STATE DOCUMENTS COLLECTION

AUG 12 1990

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

SURFACE WATER QUALITY OF THE STILLWATER STATE FOREST AND SWAN RIVER STATE FOREST 1976 - 1983

BY

BILL SCHULTZ, HYDROLOGIST
FORESTRY DIVISION
DEPARTMENT OF STATE LANDS

NOVEMBER 1984

PLEASE RETURN

ACKNOWLEDGEMENTS

Thanks to all the stream gagers and sample collectors from over the years: Pete Bengeyfield, Pete Metzmaker, John Westenberg, and Bob Harrington. Thanks to L.W. Crain for providing access to the Crain's Ranch station. Thanks to Bob White for his daily reading of the staff gage at Crain's Ranch in 1983. Special thanks to Jane Markland for the fine job of typing.

Portions of the format for this report were adapted from "Water Quality on the Gallatin National Forest 1970-1978" by Stephen P. Glasser and Alice J. Jones.

TABLE OF CONTENTS

	Page
I. INTRODUCTION	2
II. OBJECTIVES	2
III. DESCRIPTION OF AREA	2
IV. LAND USE	2
V. HYDROLOGIC SETTING	5
VI. METHODS	5
VII. GENERAL INFORMATION AND CONCLUSION	6
A. Stillwater State Forest	6
B. Swan River State Forest	10
VIII. APPENDICES	
A. Station descriptions and interpretations	A-1
B. Graphs of water quality parameters	B-1
C. Table of summary of tests of significance	C-1
D. Streamflow data - Water Year 1983, Swift Creek at Crains Ranch	D-1
E. Monthly and annual runoff figures for Swift Creek at Crains Ranch, 1973-1980 and 1983	E-1
F. Description of water quality variables	F-1
G. Stream hydrographs	G-1

LIST OF TABLES

Table 1 - Threshold Values of Selected Parameters . . . 7

LIST OF FIGURES

Figure 1 - Average Annual Total Suspended Solids Yield . 6

Figure 2 - Range and Mean of Phosphate-P 8

INTRODUCTION

The Department of State Lands (DSL) has collected 485 water quality samples at ten stations on the Stillwater State Forest and 368 samples at eight stations on the Swan River State Forest during the period 1976–1993. This report is a summary of the analysis of that data. It is written as a functional report on water quality for land managers and others interested in the quality of surface water of the Stillwater and Swan River State Forests. Additional information on the data base and statistical tests is available from the hydrologist at DSL Forestry Division headquarters in Missoula.

The data consists of basic chemical and physical parameters, as well as flow volumes. All samples and flow measurements, with the exception of the USGS gage data at Crains Ranch, are discontinuous and represent only a point in time. There are no biological, radioactive, pesticide or organic compound analyses.

OBJECTIVES

The objectives of this water quality data analysis and interpretation are:

1. Detect changes in water quality at selected sites over time to determine the trend of certain variables between years.

2. Develop predictive relationships between key variables.

3. Detect changes in water quality between selected sites to document constituent sources and watershed conditions.

4. Establish present baseline water quality parameters at monitored sites for future comparisons.

5. Provide a comprehensive database and framework for development of future water monitoring programs.

DESCRIPTION OF AREA

The Stillwater State Forest lies north of Whitefish between the Whitefish Range and the Stillwater River. It contains 90,000 acres of State owned land. There is a total of 93 square miles of state, federal, and private ownerships upstream of the ten stations on the Stillwater State Forest (see map, page 3).

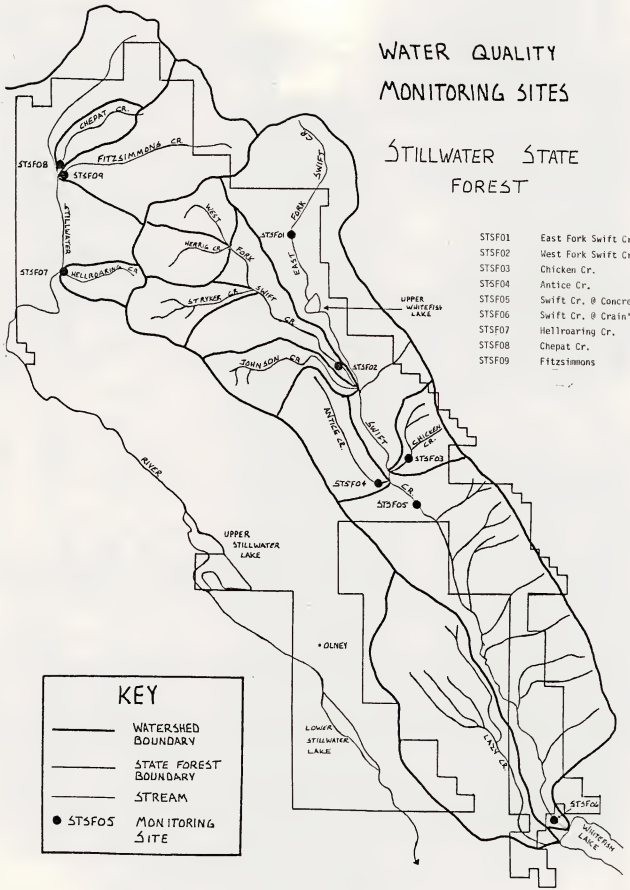
The Swan River State Forest lies in the Swan Valley between Bigfork and Condon. It contains 38,900 acres of State owned land. There is a total of 88 square miles of state, federal, and private ownership upstream of the eight stations on the Swan River State Forest (see map, page 4).

The size of the drainage areas monitored range from 1.8 square miles to 78 square miles on the Stillwater and from 5.8 square miles to 20.7 square miles on the Swan.

The stratigraphy and geomorphology of both forests are similar in that they are composed of glaciated Belt Super Group metasediments. Information on the specific landtype/geology for each station is listed with the station description. (Appendix A)

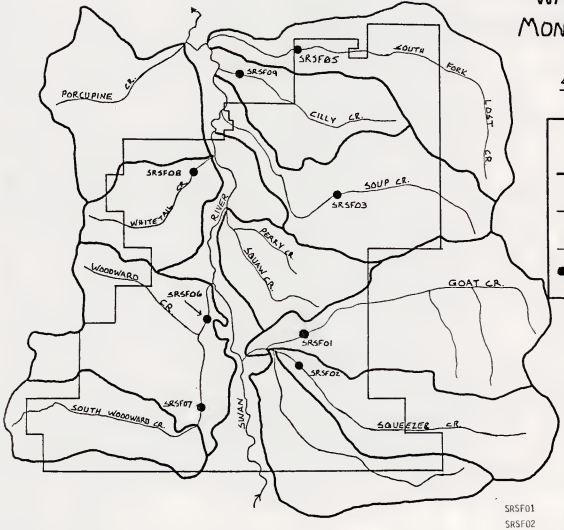
LAND USE

The primary land use on both forests is commercial timber production. Secondary


WATER QUALITY
MONITORING SITES
STILLWATER STATE
FOREST
STSF01 East Fork Swift Cr.
STSF02 West Fork Swift Cr.
STSF03 Chicken Cr.
STSF04 Antice Cr.
STSF05 Swift Cr. @ Concrete Bridge
STSF06 Swift Cr. @ Crain's Ranch
STSF07 Hellroaring Cr.
STSF08 Chepat Cr.
STSF09 Fitzsimmons
CHEPAT CR.
FITZSIMMONS CR.
STSF08
STSF09
STILLWATER RIVER
STSF07
HELLROARING CR.
WEST FORK
HEARIS CR.
STRYKER LK.
SWIFT CR.
EAST FORK
STSF01
UPPER WHITEFISH LAKE
JOHNSON CR.
STSF02
ANTICE CR.
CHICKEN CR.
STSF03
STSF04
STSF05
RIVER
UPPER STILLWATER LAKE
OLNEY
LOWER STILLWATER LAKE
LOST CR.
STSF06
WHITEFISH LAKE
KEY
WATERSHED BOUNDARY
STATE FOREST BOUNDARY
STREAM
STSF05 MONITORING SITE

WATER QUALITY MONITORING SITES

SWAN RIVER STATE FOREST



KEY

- WATERSHED BOUNDARY
- STATE FOREST BOUNDARY
- STREAM
- ● SRSF05 MONITORING SITE

SRSF01	Goat Cr.
SRSF02	Squeezer Cr.
SRSF03	Soup Cr. B
SRSF04	Soup Cr. A
SRSF05	South Fork Lost Cr.
SRSF06	Woodward Cr.
SRSF07	South Woodward Cr.
SRSF08	Whitetail Cr.
SRSF09	Cilly Cr.

uses include dispersed public recreation and a minor amount of cattle grazing. Most of the State ownership is leased for oil and gas development. The only activity to date has been seismic exploration. Information on specific land use for each station is listed with the station description.

HYDROLOGIC SETTING

All streams in this report lie on the Flathead River Basin. They are all influenced by a runoff cycle fueled by spring snowmelt coupled with spring precipitation events in April, May and June. Most streams show at least a 50-fold variation between minimum and maximum flow within a year. The months of May and June account for about 50 percent of the annual flow volume.

During the period from 1976 to 1983 water quality samples were collected and the results are discussed in this report. The following yearly variations in spring snowpack (SCS Water Supply Outlook) and streamflow measurements (USGS sites) occurred:

Water Year	May 1 Snowpack Percent of Average	Annual Streamflow Percent of Average
1976	90-110%	120%
1977	20-40%	50%
1978	90-110%	110%
1979	70-110%	90%
1980	70-90%	80%
1981	70-90%	110%
1982	110-130%	110%
1983	70-110%	100%

Overall, the eight years are about evenly split between above normal and below normal runoff. 1977 was an abnormally low flow year. 1976 was the highest. The intensive monitoring completed in 1982 and 1983 in the Stillwater, displayed near average runoff.

METHODS

Standard USGS stream gaging procedures were used. Streamflow was determined by either direct measurement with a Price AA or pygmy current meter or by interpolation from a rating curve developed for the site. The only recorded streamflow measurements used are from the USGS station number 12365800, Swift Creek near Whitefish (Crain's Ranch), period of record 1972-1981.

Water-quality parameters completed in the field include: Water temperature measured by immersing a mercury thermometer in the stream outside of the direct influence of solar radiation. Specific conductance was measured in the field with a Hach Model 16300 conductivity meter. Field alkalinity, hardness, dissolved oxygen were measured by Hach titration methods. Field pH was measured with a Hallige Lilliput Model 750 pH meter. Some variation in pH data is related to the erratic behavior of the pH test probe.

Suspended solid samples were collected with a DH-48 sampler using standard pint glass bottles. The 400 ml/sample was depth integrated across the channel. Samples were filtered with 0.45 micron disks.

Chemical analysis other than field parameters was completed by Dr. Richard Juday at the University of Montana Chemistry Department.

More complete information on methods is available from Department of State Lands - Forestry Division Hydrologist.

DATA ANALYSIS

The water quality data base is stored on floppy disks in the DB Master software format, utilized on an Apple II Plus microcomputer. Statistical analysis was completed using DB Master Stat Pak software.

STORET, EPA's national water quality data system, was not used because of difficulties with access, availability, the time involved with staying technically current with the large, dynamic system and the anticipated higher costs, primarily with time involved in data entry and analysis.

GENERAL INFORMATION AND CONCLUSIONS

Table 1 lists threshold values for selected parameters and the maximum and mean values measured.

STILLWATER STATE FOREST

Stream Discharge: The flow rate at low flow for most stations is 0.2 to 0.5 cubic feet per second (cfs) per square mile (CSM). Flow rate at high flow ranges up to 30 CSM. The maximum flow rate measured was 1,028 cfs on June 16, 1982 at Swift Creek at Crain's Ranch.

Suspended Solids: The total suspended solids concentration and average annual yields at stations upstream from Swift at Crain's Ranch show sedimentation rates close to that expected for glaciated Belt geology in a natural state. (Johnson 1982; Rosquist n.d.; Cline 1982; Cline et al 1980; Potts 1984).

Total suspended solids (TSS) yields at Swift Creek @ Crain's Ranch are 10 to 20 times greater than upstream stations at high flows. The annual TSS yield at Crain's Ranch was 190 tons/square mile, eight times that of the Concrete Bridge station and 13 times the yield of the West Fork. This is due to the large supply of sediment available from mass-wasting in the lower reaches of the channel, where Swift Creek is undercutting glaciofluvial deposits. The source for 87% of the average annual sediment yield lies between the Swift Creek at concrete bridge and Swift Creek at Crain's Ranch (Figure 1).

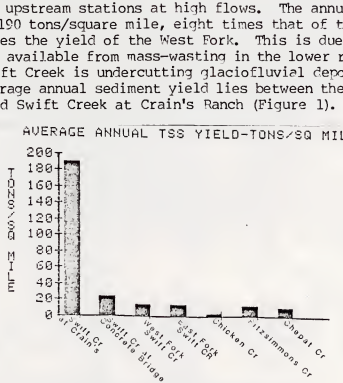


Figure 1. Average annual total suspended solids yield expressed in tons per square mile drainage area.

TABLE 1

THRESHOLD VALUES FOR SELECTED PARAMETERS WITH AVERAGE

AND MAXIMUM VALUES AND STANDARD DEVIATION.

Parameter	Threshold Value	Stillwater State Forest			Swan River State Forest		
		Max.	Mean	Std. Dev.	Max.	Mean	Std. Dev.
Alkalinity (mg/l)	None	188	98	29	274	161	29
Bicarbonate (mg/l)	None	126	76	30	203	152	32
Calcium (mg/l)	None	31	17	7	42	35	5
Chloride (mg/l)	100(a)/250(b)	1.4	0.3	0.3	1.2	0.3	0.2
Dissolved Solids (mg/l)	500(b)	167	101	38	266	201	41
Hardness (mg/l)	300(b)	154	84	30	257	143	28
Magnesium (mg/l)	100(b)	8	5	2	15	9	3
Nitrate (mg/l)	10(b)	0.199	0.074	0.049	0.27	0.11	0.07
Phosphate (mg/l)	0.050(d)	0.084	0.011	0.016	0.015	0.006	0.003
Potassium (mg/l)	None	0.4	0.2	0.07	1.1	0.5	0.3
Sodium (mg/l)	270(b)	1.9	1.0	0.30	1.6	1.0	0.4
Conductivity (micromhos/cm)	750(a)	230	120	41	300	212	32
Sulfates (mg/l)	250(b)	3.4	1.6	0.6	4	3	0.7
Suspended Solids (mg/l)	100(e)	1379	11.8	76.9	101.7	6.0	10.3
Temperature (^{0}F)	66(c)	64	44	5.4	66	45	4.5

NOTE: Upper limits of values deemed desirable for specific uses.
For reference see Appendix F - Description of Water Quality Parameters.

(a) For irrigation use.
(b) For domestic use.
(c) For aquatic use.
(d) To limit nuisance algal growth.
(e) Arbitrary - for aesthetics and aquatic habitat.

TSS yields from these mountain watersheds are supply limited. The streams nearly always have energy to transport large sediment loads. After the flush that accompanies spring runoff, the supply of available sediment is depleted.

The maximum TSS concentrations for most stations were collected May 12, 1976. For these stations the second highest value is about one-fifth the maximum.

Swift Creek at Crain's was the only station to have TSS concentrations above the 100 mg/l threshold. Seven measurements (10% of the total number of measurements) were over the 100 mg/l threshold.

TSS concentration correlates well with discharge for most stations (See Appendix C for summary of tests of significance).

The analysis of the regression equations for streamflow vs. TSS concentration shows a significant trend only at the East Fork of Swift Creek, where the 1980-1983 data show a lower concentration per unit flow than the 1976-1979 data. All other stations showed no significant trend at the 95% confidence level between data grouped in four year increments.

Temperature: Stream temperature ranged from 32 to 64° F. The maximum value measured is below the 67° F maximum value listed in the State Water Quality Standards (classification A-1). The recorded values are within the range acceptable for cold-water sportfish.

Chemical Parameters: The waters in this area can by typified as a calcium-bicarbonate type. The source of these parameters is primarily groundwater input from dissolution of the country rock. When snowmelt reaches the stream, these constituents are diluted. Specific conductance, hardness, and alkalinity also show significant dilution effects.

The water is generally soft to moderately hard. Specific conductance averages about 140 microhms/cm. Major anions and cations are well within the threshold values as listed in the parameter descriptions.

Phosphate values in Swift Creek are of special interest because of the nutrient status of Whitefish Lake. The sources of phosphate in the drainage are thought to be decomposed organic matter and phosphate compounds stored in sediments. Concentrations of this constituent increase as flow increases, indicating a surface source rather than a groundwater source. Phosphate concentration also correlates well with TSS concentrations.

The total phosphorus as phosphate data show one value above the 0.050 mg/l threshold, collected at Swift Creek at Crains Ranch on May 15, 1982. Of the total 95 phosphate measurements made in 1982 and 1983 only four exceeded 0.03 mg/l. The data shows a 300% increase in phosphate yield between Swift Creek at Concrete Bridge and Swift Creek at Crains Ranch. The data also show a higher maximum and mean phosphate concentration for the baseline, Chicken Creek, as compared with the West Fork of Swift Creek, where timber harvest has occurred periodically since the 1940's, including during the years monitoring was completed. Paired T-tests of the phosphate data show no difference at the 95% confidence level between concentrations at Swift Creek at Crain's Ranch and Chicken Creek. Phosphate yields (lbs/day) are significantly different between all stations. Progressing downstream, phosphate loading increased from the West Fork to Swift Creek at Concrete Bridge, to Swift Creek at Crains Ranch. (See Figure 2).

Nitrate values did not correlate with flow, probably due to its high soluability. Maximum nitrate concentration recorded was 0.2 mg/l, well below the 10 mg/l drinking water standard.

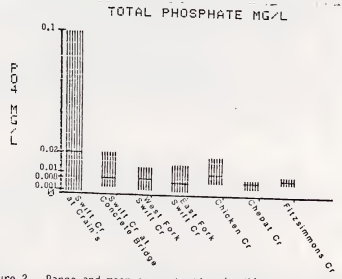


Figure 2. Range and mean concentration (mg/l) of phosphate-P. Range represented by verticle lines. Mean represented by horizontal lines.

CONCLUSIONS:

1) For the parameters tested, the waters appear to be highly suitable for domestic and irrigation use, recreational use and propagation of salmonid fisheries, with the exception of when high TSS values during flood stage.

2) Total suspended solid yields for upstream stations having the most direct impact from forest management activities are within the range expected for near natural conditions.

3) The dominate factor affecting suspended solid contribution to Whitefish Lake is the erosive channel banks occurring in the lower eight miles of Swift Creek.

4) Based on the data collected to date, logging in the upper portions of the watershed does not appear to be directly affecting the nutrient concentration of Swift Creek as it enters Whitefish Lake.

RECOMMENDATIONS:

1) DSL should continue scheduling and modifying timber harvest activities in the Swift Creek drainage to limit water yield increase to limit off-site sediment increases.

2) DSL should continue to conduct forest management activities in compliance with Flathead 208 Best Management Practices to limit on-site sediment impacts.

STUDY NEEDS:

1) Monitor Chepat Creek to obtain baseline TSS yields from an undisturbed watershed where Siyeh formation is the country rock.

2) Maintain all active stations for at least 3 years to obtain larger data base of TSS yields.

3) Continue at least one more year (1984) of chemical parameter, especially nutrient sampling, to determine if present trends continue.

4) Re-establish the Swift Creek gaging station at the Crains Ranch site with a water level recorder. A proposal is pending for funding of this station through the Whitefish County Sewer and Water District or the U. of M. Biological Station.

5) Support other agencies in groundwater monitoring in the Whitefish Lake arear so the total nutrient budget can be analyzed.

GENERAL INFORMATION AND CONCLUSIONS:

SWAN RIVER STATE FOREST

1) The statistical analysis of the streamflow discharge/TSS relationship show no significant trends at the 95% confidence level comparing 1976-1979 data against 1980-1983 data for individual stations. The analysis also showed no significant difference between stations for their total period of record.

2) The runoff characteristics of the east side and west side of the valley are very different. Runoff from the east side flows over the scarp slope of Swan

Range and has high spring flows and low late season flows. The west side of the valley flows from the dip slope of the Mission Range and is characterized by smaller peaks and higher sustained late season flow.

3) A total of twenty samples were analyzed for chemical parameters in the spring of 1982. The results show water quality similar to the upstream stations in the Stillwater State Forest. Average phosphate concentration ranged from 0.005 to 0.009 mg/l. The maximum phosphate reading was 0.015 mg/l. The east side streams are lower in most chemical constituents than west side streams.

4) For the parameters tested, the waters appear to be highly suitable for domestic and irrigation use, recreation use, and propagation of salmonid fisheries.

5) Lacking a baseline station in the Swan, it is not possible to compare "natural" sediment yields directly with the yields calculated. However, the values measured to date are within the range of values determined to be "natural" based on literature review (Johnson 1982; Rosquist; Cline 1982). It is inevitable that some timber harvesting and road construction activities result in water quality impacts, however the data collected to date suggests that those impacts may either be short lived, be subject to poor delivery mechanisms, natural levels may be lower than the literature suggests, or sampling stations and frequency are not adequate to pick up changes.

RECOMMENDATIONS:

1) The eight years of data collected on the Swan River State Forest have documented water quality conditions and no significant trends or problem areas. It is recommended that the monitoring stations on the Swan River State Forest be discontinued, at least temporarily. Future monitoring on the Swan should be limited to specific projects. For example, as pertinent projects are proposed, plans for monitoring water quality above and below the project may be appropriate and beneficial in determining the impacts of land management activities.

Individual station descriptions and interpretations are contained in Appendix A. Appendix B graphically portrays the range and mean of selected parameters. A summary table of tests of significance is contained in Appendix C. Appendix D and E list streamflow data for Swift Creek at Crains Ranch. A detailed description of water quality variables is listed in Appendix F.

REFERENCES

Cline, R., Cole, G., Megahan, W., Patton, R., and Poyondy, J. 1980. Guidelines For Predicting Sediment Yields. U.S. Forest Service Northern Region and Intermountain Region.

Cline, R.G. 1982 Rock Type Characteristics Used for Extrapolation of Coefficients in a Sediment Yield Model. USDA Forest Service. Soil, Air and Water Notes 82-1.

Glasser, S.P., and Jones, A.J. 1982 Water Quality on the Gallatin National Forest, Montana 1970-1980. United States Department of Agriculture, Forest Service. Bozeman, Montana.

Johnson, S. 1982 Kootenai National Forest Integrated Forest Plan Sediment Yield Determination. United States Department of Agriculture, Forest Service. Libby, Montana.

Potts, D. 1984 The Role of Sediment Modeling. Western Wildlands. Winter 1984.

Rosquist, A.E. n.d. Sediment Yield Calculations for Integrated Forest Planning on the Lolo National Forest. United States Department of Agriculture, Forest Service. Missoula, Montana.

APPENDIX A

STATION DESCRIPTIONS AND INTERPRETATIONS

STILLWATER STATE FOREST

STATION NUMBER : STSF01
STATION NAME : EAST FORK SWIFT CREEK
LOCATION : NW 1/4 Section 17, T34N-R23W; Bridge crossing above Upper Whitefish Lake; Staff gage on bridge.
DRAINAGE AREA : 7.6 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : The bottom land is blanketed with glacial outwash and drift. Upland areas are composed of glacial trough walls and glacial till. Bedrock types include pre-cambrian sedimentary rock of the Siyeh, Grinnell and Piegan formations. These formations are composed primarily of limestone and argillite.

NUMBER OF SAMPLES: 1976 (9), 1977 (8), 1978 (5), 1979 (9), 1980 (9), 1981(8), 1982 (9), 1983 (8). PO4-NO3 1982 and 1983 only.

LAND USE HISTORY :
- About 1,000 acres of the upper portions of the watershed burned in 1926.
- About 400 acres were clearcut in the mid to late 1960's. Salvage logging of beetle infested spruce occurred in 1982.
- Approximately six miles of primary road lies above this station.

INTERPRETATIONS : Discharge ranged from 2 cfs to 232 cfs, with a mean of 57 cfs. Total suspended solids (TSS) averaged 3 mg/l, with a range of 0.1 mg/l to 19 mg/l. Maximum TSS loading was 12 tons per day (T/D). The average annual TSS yield over 5 years is 13 tons/square mile. This is comparable with natural sedimentation rates for glaciated Belt rocks. The sediment measured at this station is transported only as far as Upper Whitefish Lake, where it is deposited.

Water temperatures averaged 42° F (range 34-50° F). The range of pH measurements was from 6.9 - 8.5 (mean 7.9). Hardness and alkanlinity are generally low to moderate (75-150 mg/l). Total dissolved solids and bicarbonate averaged approximately 125 and 100 mg/l respectively. The average specific conductance reading was 135.

The East Fork had the lowest mean phosphate concentrations of all Swift Creek stations, with a range of 0.001 to 0.015 mg/l, with mean value of 0.0047 mg/l. These values are within the range of values expected for natural water. Nitrate concentration averaged 0.112 mg/l with a maximum of 0.199, well below the drinking water maximum standard of 10 mg/l.

The East Fork was the only station on the Stillwater State Forest to show a significant trend in the sediment-discharge relationship. The sediment-discharge relationship for 1980 through 1983 was significantly lower at the 95% confidence level than the 1976-1979 data. This signifies less sediment generated per unit flow in 1980-1983 than the previous 4 years. All other stations showed no significant change at the 95% confidence level in the sediment discharge

relationship.

STATION NUMBER : STSF02
STATION NAME : WEST FORK SWIFT CREEK
LOCATION : SW 1/4 Section 34, T34N-R23W; Bridge crossing on the Antice Road; Stage measured from lag screw on downstream side of bridge; approximately one mile above confluence with East Fork.
DRAINAGE AREA : 20.25 square miles
STREAM ORDER : 4
LANDTYPE/GEOLOGY : The landtype/geology is similar to the East Fork with the exception of the upper elevation channel area. This area is fluvial breaklands formed by rapid stream downcutting. The same pre-Cambrian formations make up the bedrock.

NUMBER OF SAMPLES: 1976 (9), 1977 (8), 1978 (5), 1979 (9), 1980 (9), 1981 (10), 1982 (10), 1983 (9).

LAND USE HISTORY :
- About 1,050 acres in the upper portion of the watershed burned in 1926.
- About 3,500 acres in the watershed above this station has been harvested, mostly between the early 1950's and the early 1970's.
- About 300 acres were harvested in 1982-83 in the upper basins, mostly selective marking of beetle infested spruce. Appproximately 25 acres of this was clearcut.
- About 40 miles of road lie above this station.

INTERPRETATIONS : Discharge ranged from 4 cfs to 323 cfs with an average of 88 cfs. Total suspended solids (TSS) ranged from 41 mg/l (39 T/D) to 0.0004 mg/l (0.0004 T/D), with an average of 5 mg/l (3 T/D). The average annual TSS yield over 5 years is 14 tons per square mile. This is similar to natural erosion rates.

Water temperature ranged from 32 to 54° F, with a mean of 43° F. This is the same as the mean for undisturbed Chicken Creek.

The pH averaged 8.0. Hardness and alkalinity were in the moderate category, ranging around the 100 mg/l mark. Total dissolved solids averaged about 150 mg/l. Bicarbonate averaged about 100 mg/l. Specific conductance averaged 158 umhos/cm.

The West Fork had a mean phosphate concentration of 0.007 mg/l, with a high of 0.014 mg/l and a low of 0.002 mg/l. Statistical analysis of paired data showed phosphate concentrations at the East Fork, West Fork and Swift at Concrete Bridge stations not significantly different at the 95% confidence level. However, phosphate loading (pounds/day) was significantly different at all stations due to differences in flow rate. All concentrations measured at the West Fork were below the 0.05 mg/l threshold.

Nitrate nitrogen averaged 0.059 mg/l, with a high of 0.144 mg/l.

No statistically significant trend in the sediment/discharge relationship, in spite of the logging in the basin, was noted.

STATION NUMBER : STSF03
STATION NAME : CHICKEN CREEK - TRIBUTARY OF SWIFT CREEK
LOCATION : SE 1/4 Section 14, T33N-R23W; Arch culvert crossing on the spur road 1/4 mile north of the Lower Whitefish Road. Staff gage on the downstream side of road.
DRAINAGE AREA : 2.55 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : Upland area is steep glacial cirque headwalls. The mid-slope area consists of glacial trough walls with a small inclusion of residual soil. The lower reaches of the watershed are composed of glacial till and alluvial fan deposits.

The geology of this watershed is unique among the monitored Swift Creek watersheds in that it contains no limestone. The ridge top is composed of Grinnell formation. The lower area is composed of Appekunny formation. Both formations contain mainly argillite.

NUMBER OF SAMPLES: 1976 (10), 1977 (8), 1978 (5), 1979 (9), 1980 (9), 1981 (11), 1982 (11), 1983 (9).

LAND USE HISTORY : - No timber harvesting or road building has occurred above this station.

INTERPRETATIONS : Chicken Creek is a baseline station, hopefully indicative of water quality from an undisturbed watershed. Unfortunately, the geology of this watershed is different from the rest of the watersheds measured, resulting in some naturally occurring differences in water quality. Therefore, differences in water quality variables between this station and others cannot be directly attributed to roading and logging.

Discharge ranged from 0.5 to 32.5 cfs, with a mean of 8.5 cfs. Total suspended solids averaged 2.2 mg/l (0.1 T/D), with a range of 0.0001 mg/l (0.0001 T/D) to 13.3 mg/l (1.1 T/D). The average annual TSS yield was the lowest of all Stillwater State Forest stations, 3 tons/square mile. This value is well below the other undisturbed site, Chepat Creek, possibly because of the lack of more easily eroded limestone in the watershed.

Water temperature ranged from 34 ^{o}F to 56^{o} F with a mean of 43 ^{o}F. The pH average 7.1. Hardness, alkalinity and specific conductance were all very low, due to the absence of limestone. Most values for these variables were below 50 mg/l (micromhos/cm for conductivity). Due to the low alkalinity, this stream is poorly buffered and highly susceptible to acid rain. Bicarbonate and total dissolved solids were also very low, with averages of about 25 and 30 mg/l respectively.

The mean phosphate concentration was 0.01 mg/l, higher than the East Fork, West Fork, and Swift at Concrete bridge. The range was 0.006 to 0.019 mg/l. The source is probably a product of the decomposition of organic matter. Statistical analysis of the paired data shows no significant difference at the 95% confidence level between PO_4 concentration at Swift Creek at Crain's Ranch and Chicken Creek.

Nitrate nitrogen averaged 0.02 mg/l, with a maximum of 0.117 mg/l.

STATION NUMBER : STSF05
STATION NAME : SWIFT CREEK AT CONCRETE BRIDGE
LOCATION : SW 1/4 NW1/4 Section 24, T33N-R23W; Bridge on the Upper Whitefish Road; Stage measured from lag screw on unstream side of bridge. This station lies approximately 4 miles below the confluence of the East Fork and West Fork of Swift Creek.
DRAINAGE AREA : 50.6 square miles
STREAM ORDER : 4
LANDTYPE/GEOLOGY : The landtype above this station area composite of those included in the East Fork and West Fork, primarily glacial deposits in the mid to low elevations flanked by glacial trough walls. In addition, the valley bottom contains alluvial and silty lake deposits.

The geology is also a composite of previously listed stations.

NUMBER OF SAMPLES: 1980 (6), 1981 (11), 1982 (12), 1983 (9).

LAND USE HISTORY :
- East Fork and West Fork Swift Creek lie above this station. See Land Use History for those stations.
- In addition, approximately 1,900 acres have been harvested in the area draining this station, below the East Fork and West Fork stations. This harvest occurred mostly between 1945 and 1973. There is an additional 30 miles of road.
- Concentrated recreational use at Upper Whitefish Lake.

INTERPRETATIONS : The average discharge at this station was nearly identical to that at Swift Creek at Crain's Ranch, eight miles downstream. The mean discharge was 293 cfs, ranging from 48 to 970 cfs. TSS averaged 7 mg/l (10 T/D), with a range of 0.7 mg/l (0.07 T/D) to 35 mg/l (91 T/D). The average annual TSS yield is 24 T/mi^2. This is 10 T/mi^2/year higher than the West Fork. The source of this additional sediment is primarily from the channel banks below the confluence of the East Fork and West Fork. Here the banks are composed of glacial outwash material that is actively cutting in places. The poor stability is partially attributed to flood damage which occurred in 1974.

Water temperature ranged from 36° F to 54° F with a mean of 44° F. The pH averaged 7.7. The mean specific conductance is very similar to other Swift Creek stations with the exception of Chicken Creek. Total hardness averages just under 100 mg/l, while alkalinity is generally just over 100

mg/l. Total dissolved solids range from 100 to 140 mg/l. Bicarbonate ranges from 85 to 90 mg/l.

The phospate concentration is not significantly different from the West Fork. The mean is 0.008 mg/l, with a range of 0.003 to 0.021. These values are within the expected range for naturally occurring water.

Nitrate nitrogen averaged 0.063 mg/l with a range of 0.025 to 0.1320 mg/l.

STATION NUMBER : STSF06
STATION NAME : SWIFT CREEK AT CRAINS RANCH
LOCATION : NW 1/4 Section 5, T31N-R22W; Bridge on the Crain property, approximately 0.5 miles above Whitefish Lake and eight miles below Station STSF05.
DRAINAGE AREA : 78.0 square miles
STREAM ORDER : 4
LANDTYPE/GEOLOGY : The landtype/geology information for this station is similar to that at the upstream station, Swift Creek at Concrete Bridge.

NUMBER OF SAMPLES: 1976 (9), 1977 (8), 1978 (6), 1979 (9), 1980 (9), 1981 (11), 1982 (12), 1983 (12).

LAND USE HISTORY :
- This station lies downstream from station number STSF05. See Land Use History for this station.
- The total area harvested above this station includes over 12,000 acres, with 150 miles of road.
- Harvesting in the last several years includes the spruce beetle harvest in the upper basins by the State and clearcut harvesting on Stryker Ridge and the lower main valley floor on Plum Creek Timber Company lands.

INTERPRETATIONS : Discharge ranged from 1,028 cfs to 15 cfs, with a mean of 302 cfs. This is similar to the flow recorded 8 miles upstream. Flows are no higher at the downstream station probably because substantial water is lost to subsurface flow in the lower reaches. Streamflow data for Swift Creek is listed in Appendix D and E.

Total suspended solids averaged 49 mg/l, with a range of 0.0001 mg/l to 1,379 mg/l. A total of 7 (10%) measurements were over the 100 mg/l threshold. Eighty percent of the measurements were between 0 and 50 mg/l.

The sediment/discharge relationship at Swift Creek at Crain's Ranch is significantly higher at the 95% confidence interval than all stations in the Stillwater. This means that for a given flow rate, the TSS concentration is higher at Crain's Ranch despite the fact that most of the road building and timber harvesting has taken place above Swift Creek at Concrete Bridge and West Fork of Swift Creek Stations.

The annual TSS yield is 190 T/mi^2, eight times that of the Concrete Bridge station and 13 times the yield of the West Fork. The principal source of this sediment is high (200

ft.), steep, erosive and largely unvegetated channel banks composed of glacial outwash material that is eroded by rainstorms and is continually ravelling and slumping into the creek or into position to be transported during high spring flows. These erosive areas are located along the lower eight miles of Swift Creek.

Water temperatures ranged from 34 to 64° F, with a mean of 49° F. The pH averaged 7.9. The mean specific conductance (136 microhms/cubic centimeter) is similar to other Swift Creek stations, with the exception of Chicken Creek. Alkalinity, hardness, and specific conductance concentrations were all similar to the same parameters at the Concrete Bridge station.

This station had the highest phosphate measurement (0.084 mg/l) and the highest mean PO_4 concentration (0.02 mg/l) of all Swift Creek stations. It also had the lowest reading (0.0004 mg/l). Only one sample was measured above the 0.50 mg/l threshold. Two were between 0.40 and 0.50 mg/l. The remainder were below the 0.40 value. Fifty percent of the samples were below 0.050 mg/l. Statistical analysis of paired phosphate data showed that Swift Creek at Crain's Ranch had significantly higher loading of phosphate compared to all other upstream stations. It appears that the principal source for the phosphate lies in the lower reaches of the watershed, below the major timber harvest areas. This station, as well as Swift at Concrete Bridge, showed highly signficant direct relationship (ANOVA $P \leq 0.01$) between flow and PO_4 concentration and TSS and PO_4 concentration. This seems to indicate that the phosphate is flushed out of the system with the high flow and that it may be dependent on the sediment yield. Because of the direct relationship between flow and phosphate concentration, it appears that the phosphate is a surface water input.

Nitrate ranged from 0.002 to 0.10 mg/l.

STATION NUMBER : STST08
STATION NAME : CHEPAT CREEK - TRIBUTARY OF STILLWATER RIVER
LOCATION : NW 1/4 Section 5, T34N-R24W; Bridge crossing on the Upper Stillwater - Russky Creek Road; Staff gauge on bridge piling.
DRAINAGE AREA : 1.78 square miles
STREAM ORDER : 2
LANDTYPE/GEOLOGY : This watershed is composed of glacial cirque headwalls, glacial trough walls with glacial till and alluvial fan deposits in the bottomland.

Bedrock geology is composed of pre-Cambrian aged Grinnell, Piegan and Siyeh formations. Argillite and limestone are the dominant rock types.

NUMBER OF SAMPLES: 1976 (9), 1977 (8), 1978 (5), 1979 (9), 1980 (9), 1981 (11), 1982 (10), 1983 (4).

LAND USE HISTORY : - No timber harvest or road building has occurred above this station.

INTERPRETATIONS : Chepat Creek is a baseline watershed that has geology representative of the Swift Creek drainage stations. It lies on the west slope of the Stillwater River/Swift Creek divide.

Discharge ranged from 1 cfs to 47 cfs with a mean of 11 cfs. It has a higher discharge per square mile than all other Stillwater State Forest stations with the exception of the East Fork Swift Creek.

Average annual TSS yield over a 5 year period was 10 tons/square mile. Only Chicken Creek is lower than this. Maximum TSS concentration was 35 mg/l. This value is higher than the East Fork Swift Creek and 6 mg/l lower than the West Fork. The mean was 3.4 mg/l with a low value of 0.0001 mg/l. Maximum TSS discharge in tons/day was 3.7, less than every station except Chicken Creek.

Water temperature ranged from 32 to 52° F, with an average of 43° F. The pH ranged from 6.9 to 8.5, with a mean of 7.8. Specific conductance ranged slightly lower (71-141 microhms/cubic cm) than other Stillwater stations, with the exception of Chicken Creek. The water is moderately to very soft, with hardness generally between 50 and 100 mg/l. Alkalinity ranges from 70 to 120 mg/l. Specific conductance has a similar range.

The only phosphate data available is four samples from the spring of 1982. This data ranged from 0.006 to 0.01 mg/l. This high value is lower than the high value of any Swift Creek stations. The data from Chepat Creek is slightly higher than from neighboring Fitzsimmons Creek.

STATION NUMBER : STSF09
STATION NAME : FITZSIMMONS CREEK - TRIBUTARY OF STILLWATER RIVER
LOCATION : SW 1/4 Section 5, T34N-R24W; Bridge crossing on the Fitzsimmons Creek Road. Staff gage on downstream side of bridge.
DRAINAGE AREA : 11.3 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : This watershed has glacial till deposits in the valley bottoms with glacial cirque headwalls and glacial trough walls. Bedrock geology is composed of Grinnell, Piegan and Siyeh formations, consisting of argillite and limestone.

NUMBER OF SAMPLES: 1976 (9), 1977 (8), 1978 (5), 1979 (9), 1980 (9), 1981 (11), 1982 (10), 1983 (4).

LAND USE HISTORY : - The 1926 fire burned nearly this entire watershed.
- Approximately 115 acres were clearcut in 1963, 1971 and 1972.

INTERPRETATIONS : Discharge ranged from 3.4 to 231 cfs with an average of 68 cfs. The average is 6 cfs per square mile, the same as Chepat Creek. Total suspended solids ranged from 0.0001 to 62.3 mg/l, with an average of 3.4 mg/l. TSS loading ranged up to 26.2 tons/day with a mean of 1.7 T/D. Average annual TSS yield was 12 tons/square mile. This TSS yield is similar

to that generated by the East Fork and West Fork.

Water temperature ranged from 34° F to 52° F, with an average of 44° F. The pH averaged 7.9. The specific conductance averaged the same as the East Fork and Swift at Crains (136 microhms per cubic centimeter). Alkalinity and hardness were in the moderate range (70-120 mg/l). Total dissolved solids averaged about 100 mg/l.

Only four phosphate measurements, from the spring of 1982, were analyzed. This data ranged from 0.003 to 0.008 mg/l. The average value was 0.005. These phosphate values were slightly lower than neighboring Chepat Creek.

STATION NUMBER : STSF07
STATION NAME : HELL ROARING CREEK - TRIBUTARY OF STILLWATER RIVER
LOCATION : NW 1/4 Section 20, T34N-R24W
DRAINAGE AREA : 1.9 square miles
STREAM ORDER : 2
LANDTYPE/GEOLOGY : Most of this watershed lies on a glacial trough wall. There are some glacial till deposits in the headwaters area and alluvial fan deposits near the confluence with the Stillwater River.

Bedrock geology is composed primarily of precambrian sedimentary rocks of the Piegan and Grinnell formations.

NUMBER OF SAMPLES: 1976 (9).

LAND USE HISTORY : - No timber harvest or road construction has occurred in this drainage.

INTERPRETATIONS : Due to the short period of record, the statistical comparisons between this station and others were not made.

This is not an appropriate baseline station because it lacks Siyeh limestone.

The data shows chemical parameters similar to Chicken Creek with discharge less "flashy" than neighboring Chepat Creek. Total suspended solids concentration was considerably less than Chepat Creek, possibly reflecting the lack of limestone in the watershed.

STATION NUMBER : STSF04
STATION NAME : ANTICE CREEK - TRIBUTARY OF SWIFT CREEK
LOCATION : SW 1/4 Section 14, T33N-R23W
DRAINAGE AREA : 5.6 square miles
STREAM ORDER : 2
LANDTYPE/GEOLOGY : The upper elevations of this watershed are made up of glacial trough walls and headwalls. The bottomland is composed primarily of glacial till with some lucustrine and alluvium deposits. Bedrock geology is almost entirely Siyeh limestone.

NUMBER OF SAMPLES: 1976 (9).

LAND USE HISTORY : - About 930 acres clearcut, mostly in the early 1960's and 1970's.
- Approximately 24 miles of road has been constructed in this drainage.

INTERPRETATIONS : Due to the short period of record, the statistical comparisons between this station and others were not made.

The data show similar water quality as other Swift Creek tributaries and no special conditions appear to exist.

STATION NUMBER : CCSF01
STATION NAME : CYCLONE CREEK - TRIBUTARY OF COAL CREEK, NORTH FORK FLATHEAD RIVER DRAINAGE
LOCATION : NE 1/4 Section 35, T34N-R21W
DRAINAGE AREA : 13.5 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : This watershed is composed primarily of glacial trough walls and glacial till deposits. Bedrock geology is composed primarily of precambrian aged Roosville argillite. Also present are Kintla and Piegan argillites and Siyeh limestone.

NUMBER OF SAMPLES: 1978 (8), 1979 (9).

LAND USE HISTORY : - A large portion of this watershed burned in 1830, 1910 and 1926.
- Approximately 925 acres have been harvested, mostly in the late 1950's and early 1970's.

INTERPRETATIONS : Due to the short period of record, the statistical comparisons between this station and others were not made.

Hardness, alkalinity and specific conductance were all very low, comparable to Chicken Creek. TSS concentrations were lower than most Swift Creek Stations, because of the storage provided upstream by Cyclone Lake.

STATION NUMBER : SRSF01
STATION NAME : GOAT CREEK
LOCATION : NW 1/4 Section 16, T23N-R17W; Bridge crossing on old Squeezer Road, 0.1 mile off Goat Creek Road. Stage measured on staff gage located on upstream side of bridge.
DRAINAGE AREA : 20.7 square miles
STREAM ORDER : 4
LANDTYPE/GEOLOGY : This drainage is characterized by steep alpine and cirque headwalls at the upper elevation headquarters area. Numerous feeder streams exist within the drainage; with steep (40-60%) glacial trough walls at mid elevations, deep glacial till in the stream bottoms, and colluvium at the mouths of the larger streams. Scattered areas of structured breaklands occur on several ridges at mid-elevation.

Deep glacial till originating from quartzite, calcareous argillite, and limestone comprise the valley bottom. Poorly drained alluvium exists on the channel bottom above the station.

NUMBER OF SAMPLES: 1976 (10), 1977 (8), 1978 (8), 1979 (8), 1980 (10), 1981 (11), 1982 (13), 1983 (7).

LAND USE HISTORY :
- Approximately 480 acres were clearcut in the late 1950's and mid to late 1960's.
- Approximately 1320 acres were partially cut in the late 1950's, 1960's and early 1970's.
- About 700 acres in the drainage burned in 1973.
- Approximately 15 miles of primary and secondary roads exist above the station.

INTERPRETATIONS : Discharge ranged from 4 to 201 cfs. Only Woodward Creek produced less water per square mile drainage area at peak flow. Total suspended solids (TSS) ranged from 47.9 mg/l (12.1 T/D) to 0.1 mg/l (.003 T/D) with a mean of 5.6 mg/l (1.6 T/D). The average annual TSS yield for a five year period is 9 tons/square mile/year. With the exception of Woodward Creek, this is the lowest yield on the forest.

Water temperature ranged from 32 to 51° F with a mean of 44° F. The pH averaged 8.2. Specific conductance averaged 244 microhms/cm. The hardness and alkalinity of the water was in the moderate category.

STATION NUMBER : SRSF02
STATION NAME : SQUEEZER CREEK
LOCATION : NW 1/4 Section 21, T23N-R17W; Bridge crossing on secondary road off of old Squeezer Road; stage is measured on staff gage located on upstream side of bridge.
DRAINAGE AREA : 14.2 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : Alpine and cirque headwalls exist at the upper end of the drainage, with shallow glacial till surrounding a few isolated alpine lakes. Structured breaklands and glacial trough walls occur below this. Deep glacial till exists in

the channel bottom, originating from limestone and calcareous argillite in the upper end of the drainage and changing to quartzite substrate in the Swan Valley bottom.

NUMBER OF SAMPLES: 1976 (10), 1977 (8), 1978 (7), 1979 (8), 1980 (10), 1981 (11), 1982 (13), 1983 (7).

LAND USE HISTORY :
- Approximately 84 acres were clearcut in the late 1950's and 1960's.
- Approximately 300 acres were partially cut in 1963 and 1972, yielding an equivalent clearcut of 115 acres.
- Approximately 7.5 miles of primary and secondary roads exist above the station.
- An undetermined acreage was harvested on BN ownership in 1982.

INTERPRETATIONS : Discharge ranged from 4 to 176 cfs with an average of 52 cfs. Total suspended solids ranged from 0.2 mg/l to 48.5 mg/l, with an average of 8 mg/l. The average annual TSS yield over 5 years is 11 tons/square mile.

Water temperature ranged from 32 to 54 ^{o}F with an average of 44 ^{o}F. The pH averaged 8.1. Hardness, alkalinity and conductivity readings are generally 10 to 20 units lower at this station as compared to Goat Creek.

STATION NUMBER : SRSF03
STATION NAME : SOUP CREEK B
LOCATION : SW 1/4 Section 27, T24N-R17W; Bridge crossing on the Soup Creek Loop Road; adjacent to Soup Creek campground; stage measured at staff gage on downstream side of bridge.

DRAINAGE AREA : 5.76 square miles
STREAM ORDER : 2
LANDTYPE/GEOLOGY : Landtypes include predominately structured breaklands with glacial trough walls at mid-elevations. Both types have accompanying steep slopes (>50%) and shallow soils. Glacial till is common in the channel bottom, and colluvium is found in the vicinity of the valley bottom at the stream station. Bedrock is calcareous argillite and limestone.

NUMBER OF SAMPLES: 1976 (10), 1980 (6), 1981 (11), 1982 (13), 1983 (7).

LAND USE HISTORY :
- About 200 acres above the station were harvested (clearcut) in the early to mid 1960's.
- About 50 acres were clearcut in 1981 and 1982.
- About 4 miles of secondary roads exist above this station.

INTERPRETATIONS : Discharge ranged from 2 to 88 cfs with a mean of 29 cfs. The average runoff was 5 cfs/square mile. The highest TSS concentrations on the forest was collected at this station (102 mg/l). The average TSS concentration was 8 mg/l with 85% of the measurements is the 0 to 10 mg/l range. Soup Creek has the highest average annual TSS yield, 22 T/mi.^{2}.

A unit above this station was cable logged in the summer of 1981. Above and below TSS samples were taken before, during and after the logging to document the impacts on water

quality. Paired t-tests of the data show that a significant difference at the 95% confidence level existed before and after the logging. Therefore, the results of this monitoring are not conclusive.

Water temperature ranged from 34 to 53° F, with an average of 43° F. The pH averaged 8.2. The specific conductance is similar to South Fork Lost Creek, higher than Woodward Creek and lower than Goat Creek.

Hardness and alkalinity were generally in the 150-170 mg/l range, varying with the flow rate.

STATION NUMBER : SRSF05
STATION NAME : SOUTH FORK LOST CREEK
LOCATION : SW 1/4 Section 4, T24N-R17W; Bridge crossing 2 miles off South Lost Creek Road, stage measured with staff gage on downstream side of bridge.
DRAINAGE AREA : 16.2 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : Alpine and cirque headwalls form the headwaters along the Swan divide. Glacial trough walls and structured breaklands occur at mid-elevations along both the main channel and tributaries. Shallow glacial till is found in scattered areas in the trough walls and headwalls where slope is below 40%. Deep glacial till from limestone and non-calcareous argillite is found along the channel bottoms of South Fork Lost Creek and Cliff Creeks, and at least one tributary stream has an alluvial fan at its mouth.

NUMBER OF SAMPLES: 1976 (9), 1977 (7), 1978 (7), 1979 (8), 1980 (10), 1981 (11), 1982 (11), 1983 (7).

LAND USE HISTORY :
- Approximately 630 acres were clearcut in the late 1950's, 1960's, and early 1970's; mostly in the upper areas of the drainage.
- Approximately 30 acres were selectively logged in the late 1950's.
- Approximately 10 miles of primary and secondary roads exist above this station.

INTERPRETATIONS : Discharge ranged from 8 to 339 cfs, the highest recorded on the Swan stations. South Lost Creek consistantly has the highest flow per square mile drainage area, with a high value of 21 CSM.

Total suspended solids (TSS) ranged from 0.2 mg/l to 74 mg/l, with an average of 5.4 mg/l. TSS yield averaged 2.7 tons/day. Average annual TSS yield over 5 years is 13 tons per square mile.

Water temperature ranged from 33 to 52° F, with an average of 44° F. Specific conductance ranged from 152 to 285 micromhos per cm. The hardness and alkalinity are in the moderate range.

STATION NUMBER : SRSF06
STATION NAME : WOODWARD CREEK
LOCATION : SE 1/4 Section 12, T23N-R18W; Bridge crossing on Lower Whitetail Road; Stage measured on staff gage on upstream side of bridge.
DRAINAGE AREA : 14.7 square miles
STREAM ORDER : 4
LANDTYPE/GEOLOGY : Alpine headwalls comprise the headwaters region of the stream with thin glacial till from calcareous argillite at mid-elevations. Scattered pockets of deep till occur within these mid-elevational areas, and predominate at lower elevation in the channel bottom. Deep, reworked till is found in the general area of the station.

Bedrock is primarily limestone with calcareous argillite present in areas where scouring and downcutting has occurred.

NUMBER OF SAMPLES: 1976 (10), 1977 (8), 1978 (8), 1979 (8), 1980 (10), 1981 (11), 1982 (13), 1983 (7).

LAND USE HISTORY :
- Approximately 700 acres were clearcut in the early and mid 1960's, primarily in the middle and lower elevation areas of the drainage.
- Approximately 1700 acres were selectively logged in the 1960's and early 1970's.
- Approximately 25 miles of primary and secondary roads exist above the station.

INTERPRETATIONS : Discharge ranged from 47 to 129 cfs, with an averge of 85 cfs. The discharge per unit drainage area at low flow is about 10 times greater at this station compared with stations on the east side of the valley. This is because of the easterly aspect, limestone geology and higher percentage of subsurface recharge.

Total suspended solids (TSS) concentrations and yields are the lowest of all stations on the Swan. The maximum concentration recorded is 16 mg/l. The average annual TSS yield over a five year period is 6 tons per square mile, approximately one-half the yield from South Fork Lost Creek or Squeezer Creek.

The bridge at the station site was replaced in August 1982. TSS measurements above and below the construction site showed a 7 mg/l (1.4 T/D) increase in TSS. This increase diminished soon after construction activities terminated.

Water temperature ranged from 34 to 66° F, with an average of 47 °F. Forty-three percent of the readings were between 45-50 °F.

Specific conductance was the lowest of all Swan stations, with an average of 180 microhms per cm. Hardness and alkalinity were also lower than other Swan stations.

STATION NUMBER : SRSF07
STATION NAME : SOUTH WOODWARD CREEK

LOCATION : SW 1/4 Section 25, T23N-R18W
DRAINAGE AREA : 10.4 square miles
STREAM ORDER : 2
LANDTYPE/GEOLOGY : This drainage begins with alpine headwalls at the highest elevations, with steep structured breaklands and shallow glacial till on moderate slopes. Glacial trough walls occur at mid-elevation along the length of the main channel. Moderately shallow till and residual soils are found at mid-elevation along the lower reaches of the stream; occurring with deep glacial till from calcareous argillite at the mid-elevations and channel bottoms.

Bedrock is primarily limestone and calcareous argillite.

NUMBER OF SAMPLES: 1976 (9).

LAND USE HISTORY :
- At least 2500 acres burned in the central part of the drainage in 1934; about 1300 acres above the station.
- Approximately 18 miles of primary and secondary roads exist above this station.
- An undetermined number of acres have been harvested on private ownership in recent years.

INTERPRETATIONS : Due to the short period of record, the standard statistical comparisons were not made. This station has low peak flows and high sustained summer flow. TSS concentrations were low, comparable to main Woodward Creek.

STATION NUMBER : SRSF08
STATION NAME : WHITETAIL CREEK
LOCATION : NW 1/4 Section 25, T24N-R18W
DRAINAGE AREA : 8.0 square miles
STREAM ORDER : 3
LANDTYPE/GEOLOGY : Alpine headwalls occur in the higher elevation headquarters, followed by thin glacial till from calcareous argillite on 20-60% slopes at mid-elevation. Moderately shallow till and residual soils occur at mid-elevation further down into the channel. Deep glacial till from calcareous argillite is found along most of the main stream channel bottom, and changes to deep reworked till near the station site. Some scattered, poorly drained alluvial land is present near the station.

Bedrock is primarily limestone, with calcareous argillite present in stream channel ares.

NUMBER OF SAMPLES: 1976 (7).

LAND USE HISTORY :
- About 1100 acres were clearcut throughout the drainage in the 1960's and 1970's. Cuts were primarily in the lower areas of the drainage, but several were done at higher elevational areas as well.
- About 1150 acres were selectively logged in the 1960's and 1970's.
- About 90 acres harvested in 1982 and 1983.
- Approximately 10 miles of primary and secondary roads exist

above the station.

INTERPRETATIONS : Due to the short period of record, the standard statistical analysis was not completed for this station. Discharge per unit drainage area was low at peak flows, but had high sustained summer flow. TSS concentration was low, due to low gradient and backwater storage in sloughs. Hardness and alkalinity were about 50 mg/l higher than Woodward Creek.

STATION NUMBER : SRSP09
STATION NAME : CILLY CREEK
LOCATION : NW 1/4 Section 7, T24N-R17W
DRAINAGE AREA : 8.8 square miles
STREAM ORDER : 3
LANDTYPE GEOLOGY : Alpine headwalls occur at the upper elevation headwaters, structured breaklands at mid-elevations. Deep glacial till from limestone and calcareous argillite occurs at lower elevations along the channel.

NUMBER OF SAMPLES: 1976 (8).

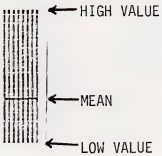
LAND USE HISTORY : - Approximately 614 acres were clearcut in the 1960's and early 1970's, throughout the drainage.
- 459 acres were selectively logged in 1968.
- Approximately 19 miles of primary and secondary roads exist above this station.

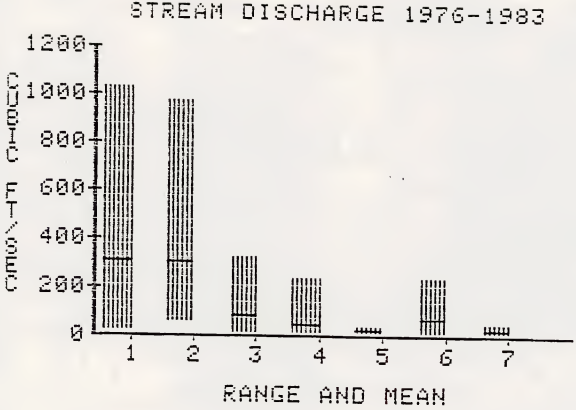
INTERPRETATIONS : Due to the short period of record, the standard statistical analysis was not completed for this station. Discharge per unit drainage area is lower for this station than other Swan stations at high flow and is similar to other east side stations at low flows. TSS concentration ranged from 0.3 to 25.4 mg/l.

APPENDIX B

GRAPHS OF WATER QUALITY PARAMETERS

Explanation For
Range and Mean Graphs





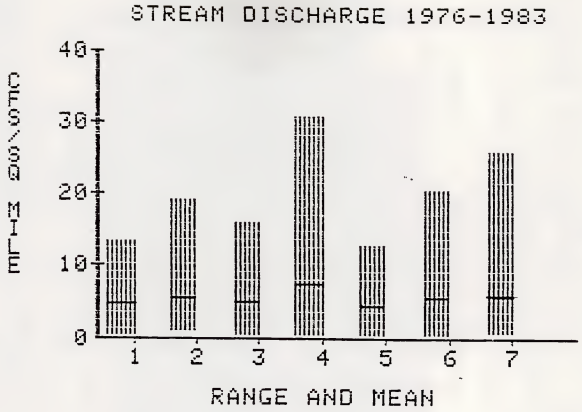
STILLWATER STATE FOREST

KEY

DISCHARGE

CFS

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	1028	15	302	76 - 83	258	75
2	Swift @ Concrete	970	48	293	80 - 83	240	38
3	West Fork Swift	323	4	88	76 - 83	81	69
4	East Fork Swift	232	2	57	76 - 83	60	65
5	Chicken	33	0.5	9	76 - 83	8	72
6	Fitzsimmons	231	3	68	76 - 83	54	65
7	Cheput	47	1	11	76 - 83	10	64



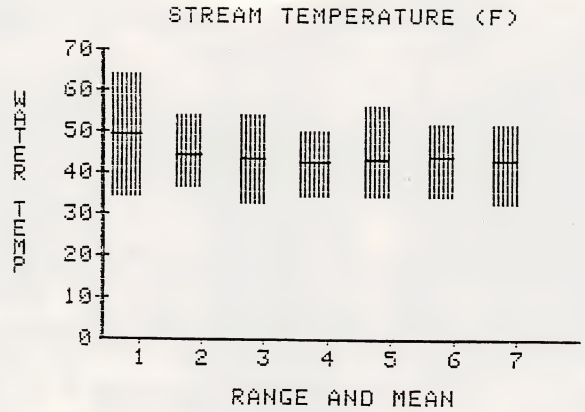
STILLWATER STATE FOREST

KEY

DISCHARGE

CFS/SQ. MILE (CSM)

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	13.2	0.2	3.9	76 - 83	-	75
2	Swift @ Concrete	19.2	0.9	5.8	80 - 83	-	38
3	West Fork Swift	16.0	0.2	4.3	76 - 83	-	69
4	East Fork Swift	30.5	0.3	7.5	76 - 83	-	65
5	Chicken	12.7	0.2	3.3	76 - 83	-	72
6	Fitzsimmons	25.8	0.5	5.9	76 - 83	-	65
7	Chepat	20.4	0.3	6.0	76 - 83	-	64



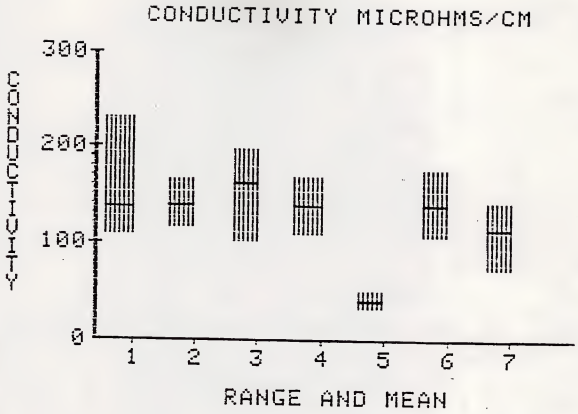
STILLWATER STATE FOREST

KEY

STREAM TEMPERATURE

DEGREES FAHRENHEIT

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	64	34	49	76 - 83	7	72
2	Swift @ Concrete	54	36	44	80 - 83	5	36
3	West Fork Swift	54	32	43	76 - 83	5	66
4	East Fork Swift	50	34	42	76 - 83	4	63
5	Chicken	56	34	43	76 - 83	4	69
6	Fitzsimmons	52	34	44	76 - 83	4	63
7	Chepat	52	32	43	76 - 83	5	64



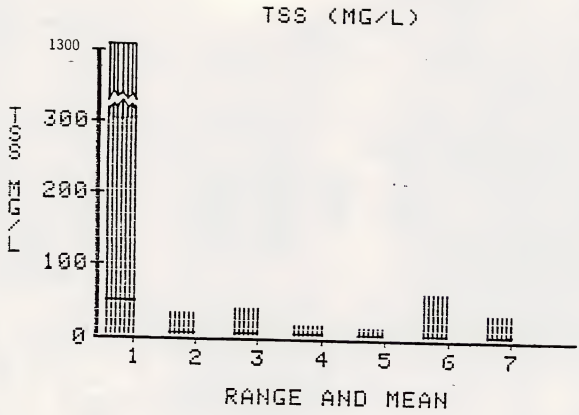
STILLWATER STATE FOREST

KEY

CONDUCTIVITY

MICROMHOS/CENTIMETER

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	230	108	136	76 - 83	22	65
2	Swift @ Concrete	164	115	138	80 - 83	15	36
3	West Fork Swift	195	100	158	76 - 83	22	58
4	East Fork Swift	167	106	135	76 - 83	17	53
5	Chicken	50	30	39	76 - 83	6	58
6	Fitzsimmons	173	105	136	76 - 83	19	52
7	Chepat	141	71	112	76 - 83	17	52



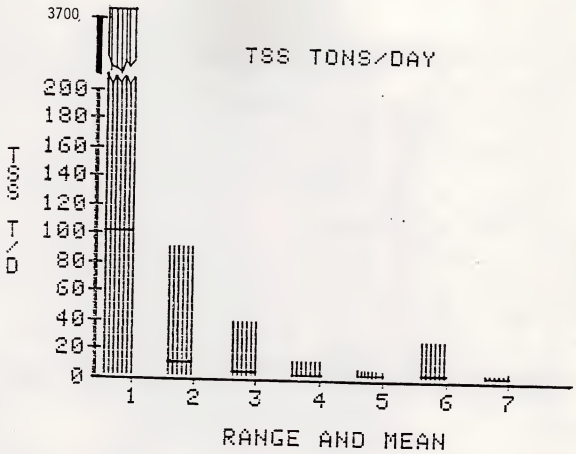
STILLWATER STATE FOREST

KEY

TOTAL SUSPENDED SOLIDS

MG/L

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	1379	0.0001	49	76 - 83	163	75
2	Swift @ Concrete	35	0.7	7	80 - 83	8	38
3	West Fork Swift	41	0.0004	5	76 - 83	8	68
4	East Fork Swift	19	0.1	3	76 - 83	4	63
5	Chicken	13	0.0001	2	76 - 83	3	69
6	Fitzsimmons	62	0.0001	4	76 - 83	10	65
7	Cheput	35	0.0001	3	76 - 83	6	65



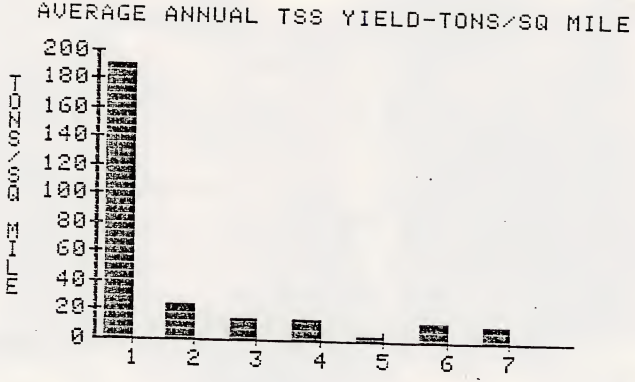
STILLWATER STATE FOREST

KEY

TOTAL SUSPENDED SOLIDS (TSS)

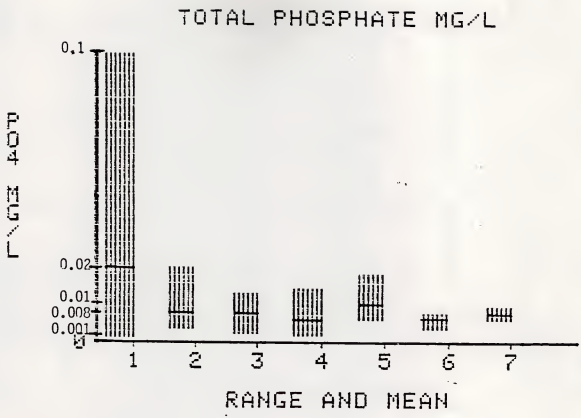
TONS/DAY

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	3761	0.0001	103	76 - 83	448	73
2	Swift @ Concrete	91	0.07	10	80 - 83	17.9	37
3	West Fork Swift	39	0.0004	3	76 - 83	6	68
4	East Fork Swift	12	0.002	1	76 - 83	2	63
5	Chicken	1.1	0.0001	0.1	76 - 83	0.2	68
6	Fitzsimmons	26.2	0.0001	1.7	76 - 83	6	65
7	Chepat	3.7	0.0001	0.2	76 - 83	0.7	64



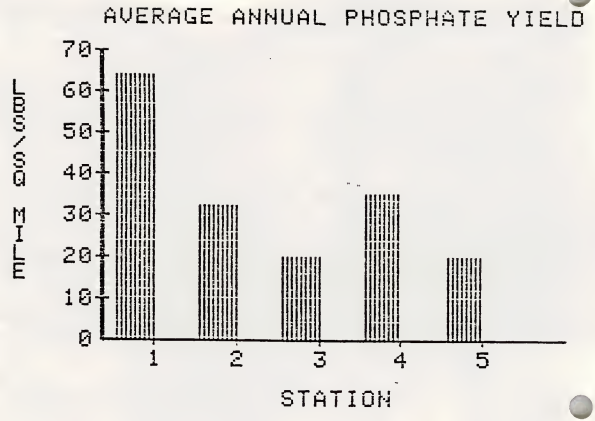
STILLWATER STATE FOREST
KEY
AVERAGE ANNUAL TSS YIELD
TONS/SQ. MILE

#	Stream	Average Annual Yield	Standard Deviation	# of Years Averaged
1	Swift @ Crains	190	251	5
2	Swift @ Concrete	24	8	3
3	West Fork Swift	14	8	5
4	East Fork Swift	13	6	5
5	Chicken	3	3	5
6	Fitzsimmons	12	14	4
7	Chepat	10	12	4



STILLWATER STATE FOREST
KEY
TOTAL PHOSPHATE (PO4)
MG/L

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	0.084	0.0004	0.02	82 - 83	0.02	20
2	Swift @ Concrete	0.021	0.003	0.003	82 - 83	0.005	19
3	West Fork Swift	0.014	0.002	0.007	82 - 83	0.004	17
4	East Fork Swift	0.015	0.001	0.0047	82 - 83	0.004	14
5	Chicken	0.019	0.006	0.01	82 - 83	0.003	18
6	Fitzsimmons	0.008	0.003	0.005	82	0.002	4
7	Chepat	0.01	0.006	0.007	82	0.002	4



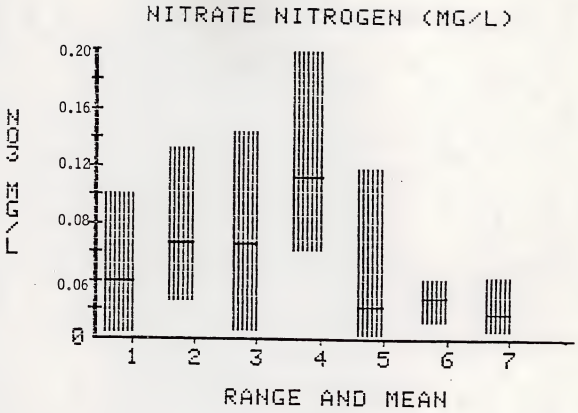
STILLWATER STATE FOREST

KEY

AVERAGE ANNUAL PHOSPHATE (P04) YIELD

LBS/SQ. MILE

#	Stream	Average Annual Yield	Standard Deviation	# of Years Averaged
1	Swift @ Crains	64	33	2
2	Swift @ Concrete	32	17	2
3	West Fork Swift	20	2	2
4	East Fork Swift	35	-	1
5	Chicken	20	1	2



STILLWATER STATE FOREST

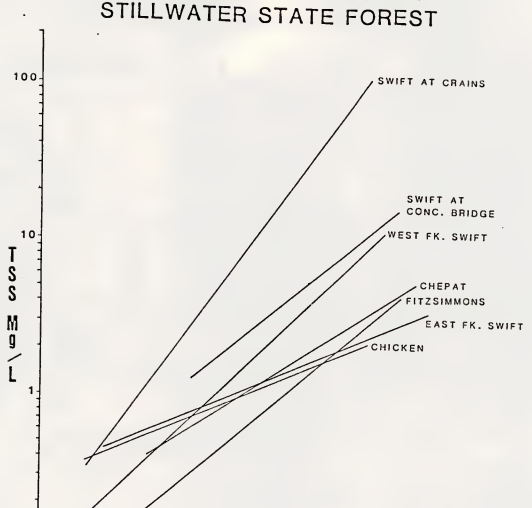
KEY

NITRATE NITROGEN (NO3)

MG/L

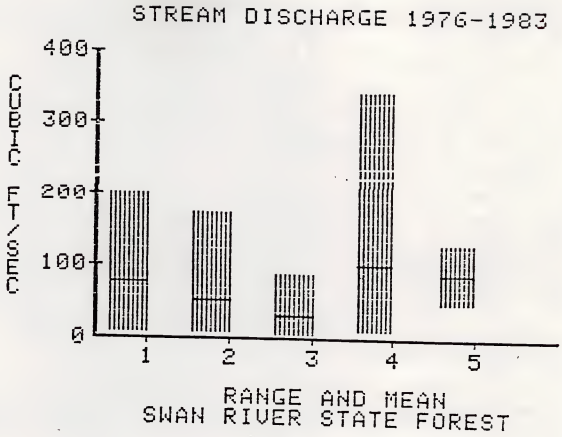
#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Swift @ Crains	0.1	0.002	0.04	82 - 83	0.03	19
2	Swift @ Concrete	0.13	0.025	0.063	82 - 83	0.03	18
3	West Fork Swift	0.14	0.004	0.059	82 - 83	0.04	16
4	East Fork Swift	0.199	0.06	0.112	82 - 83	0.05	13
5	Chicken	0.117	0.001	0.02	82 - 83	0.03	17
6	Fitzsimmons	0.041	0.01	0.026	82	0.01	4
7	Chepat	0.043	0.004	0.0173	82	0.02	4

SEDIMENT RATING CURVE
STILLWATER STATE FOREST



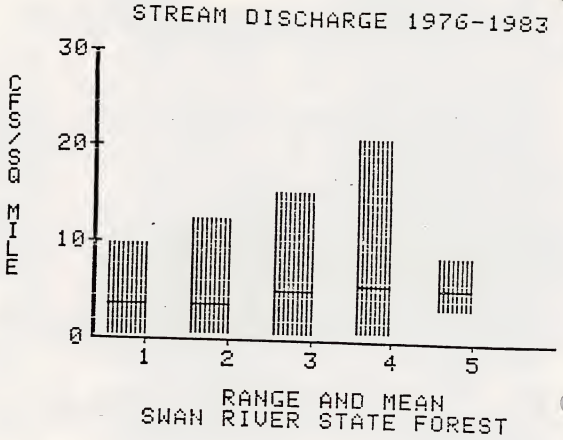
REGRESSION EQUATIONS AND STATISTICAL SUMMARY

STREAM	REGRESSION EQUATION	R^2	STD ERROR OF ESTIMATE
Swift @ Crains	Log TSS (Mg/L) = 0.50 + 1.37 Log CSM	.50	0.66
Swift @ Conc. Br.	Log TSS (Mg/L) = .1233 + 0.8367 Log CSM	.60	0.2905
West Fork Swift	Log TSS (Mg/L) = -0.1107 + 0.9635 Log CSM	.39	0.6059
East Fork Swift	Log TSS (Mg/L) = -0.0955 + 0.4316 Log CSM	.24	0.4339
Chicken	Log TSS (Mg/L) = -0.1336 + 0.4246 Log CSM	.07	0.6930
Fitzsimmons	Log TSS (Mg/L) = -0.5152 + 0.8832 Log CSM	.21	0.8301
Chepat	Log TSS (Mg/L) = -0.1929 + 0.6578 Log CSM	.20	0.6487



KEY
DISCHARGE
CFS

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	201	4	76	76 - 83	54	75
2	Squeezer Creek	176	4	52	76 - 83	45	74
3	Soup Creek "B"	88	2	29	76, 80 - 83	26	47
4	South Fork Lost	339	8	95	76 - 83	78	70
5	Woodward	129	47	85	76 - 83	20	75

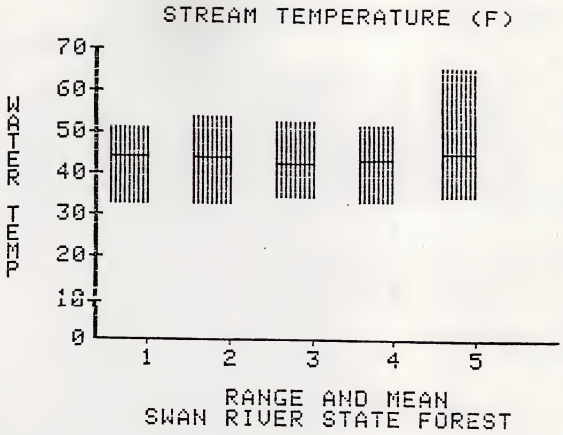


KEY

DISCHARGE

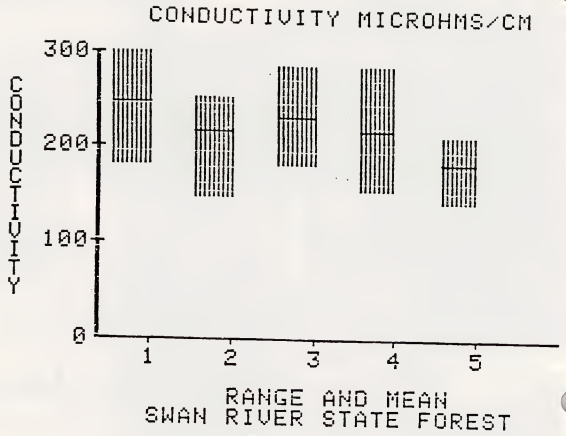
CFS/SQ. MILE (CSM)

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	9.7	0.2	3.7	76 - 83	-	75
2	Squeezer Creek	12.4	0.3	3.7	76 - 83	-	74
3	Soup Creek "D"	15.3	0.3	5.1	76, 80 - 83	-	47
4	South Fork Lost	21.0	0.5	5.9	76 - 83	-	70
5	Koooward	8.8	3.2	5.8	76 - 83	-	75



KEY
STREAM TEMPERATURE
DEGREES FAHRENHEIT

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	51	32	44	76 - 83	4	73
2	Squeezer Creek	54	32	44	76 - 83	4	72
3	Soup Creek "B"	53	34	43	76, 80 - 83	4	46
4	South Fork Lost	52	33	44	76 - 83	4	68
5	Woodward	66	34	47	76 - 83	5	72

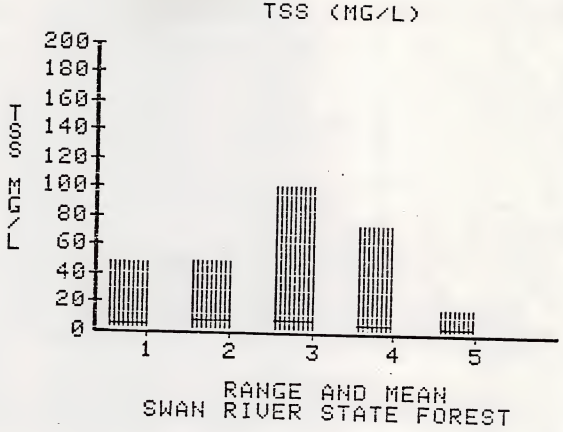


KEY

CONDUCTIVITY

MICROMHOS/CENTIMETER

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	300	186	244	78 - 83	31	55
2	Squeezer Creek	250	146	213	78 - 83	21	54
3	Soup Creek "B"	285	180	230	80 - 83	28	36
4	South Fork Lost	285	152	214	78 - 83	30	53
5	Woodward	210	141	180	77 - 83	16	58

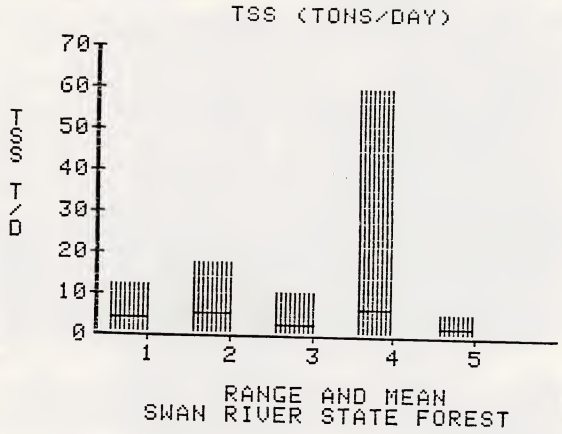


KEY

TOTAL SUSPENDED SOLIDS

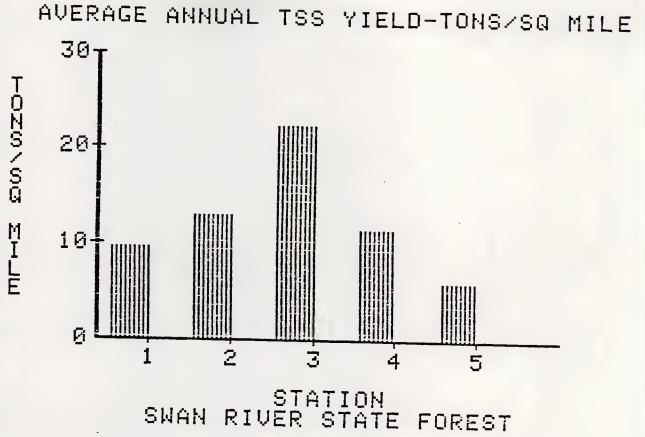
MG/L

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	47.9	0.1	5.6	76 - 83	7.4	75
2	Squeezer Creek	48.5	0.2	7.9	76 - 83	11.2	74
3	Soup Creek "B"	101.7	0.1	8.0	76, 80 - 83	17.7	47
4	South Fork Lost	74.0	0.2	5.4	76 - 83	9.6	70
5	Woodward	16.2	0.1	3.4	76 - 83	2.9	75



KEY
TOTAL SUSPENDED SOLIDS
TONS/DAY

#	Stream	High	Low	Mean	Period of Record	Standard Deviation	# of Observations
1	Goat Creek	12.1	0.003	1.6	76 - 83	2.5	75
2	Squeezer Creek	17.6	0.003	2.1	76 - 83	3.8	74
3	Soup Creek "D"	10.4	0.001	1.0	76, 80 - 83	2.2	47
4	South Fork Lost	60.1	0.008	2.7	76 - 83	7.8	70
5	Woodward	5.3	0.02	1.0	76 - 83	0.9	75



KEY

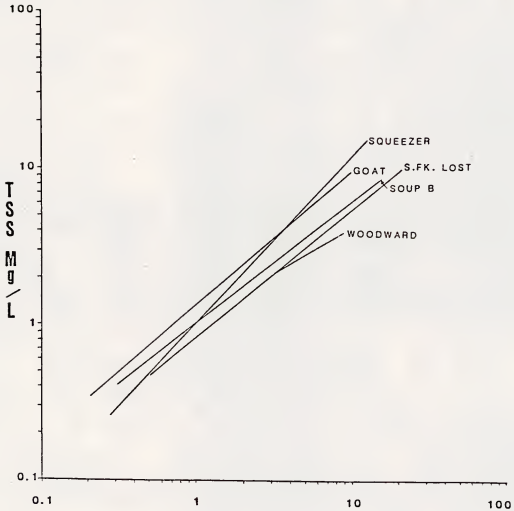
AVERAGE ANNUAL TSS YIELD

TONS/SQ. MILE

AVERAGE ANNUAL YIELD

#	Stream	Average Annual Yield	Standard Deviation	# of Years Averaged
1	Goat Creek	9.4	2.9	5
2	Squeezer Creek	12.9	3.1	5
3	Soup Creek "B"	22.2	12.7	4
4	South Fork Lost	11.3	7.1	5
5	Woodward	5.8	2.4	5

SEDIMENT RATING CURVE
SWAN RIVER STATE FOREST



REGRESSION EQUATIONS AND STATISTICAL SUMMARY

STREAM	REGRESSION EQUATION	R^2	STD ERROR OF ESTIMATE
Goat	Log TSS (Mg/L) = 0.1182 + 0.8714 Log CSM	.45	.3904
Squeezer	Log TSS (Mg/L) = 0.1008 + 1.0892 Log CSM	.59	.3941
Soup B	Log TSS (Mg/L) = 0.0034 + 0.7911 Log CSM	.34	.5262
So. Fork Lost	Log TSS (Mg/L) = 0.0877 + 0.8320 Log CSM	.43	.4307
Woodward	Log TSS (Mg/L) = 0.0479 + 0.5708 Log CSM	.03	.3559

APPENDIX C

SUMMARY OF TESTS OF SIGNIFICANCE

STILLWATER STATE FOREST

SUMMARY OF TESTS OF SIGNIFICANCE

Parameter & Sort	Swift Cr. at Crains	Swift Cr. at Conc. Pr.	West Fork Swift Cr.	East Fork Swift Cr.	Chicken Cr.	Chepat Cr.	Fitzsimmons Cr.
LG CFS vs LG TSS (Mg/l)							
76-79	NS	ID	HS	S	S	HS	S
80-83	HS	HS	HS	HS	NS	HS	HS
76-83	HS	ID	HS	HS	S	HS	HS
LG CFS vs LG TSS (Mg/l)							
76-79	NS	ID	HS	S	HS	HS	S
80-83	HS	HS	HS	HS	NS	HS	HS
76-83	HS	ID	HS	HS	S	HS	HS
LG CFS vs LG SP COND							
76-79	NS	ID	S	HS	HS	HS	HS
80-83	HS	HS	HS	HS	HS	HS	HS
76-83	HS	ID	HS	HS	HS	HS	HS
LG STAGE vs LG CFS	HS	HS	HS	HS	HS	HS	HS
LG CFS vs LG PO4							
82-83	HS	HS	S	S	NS	ID	ID
LG TSS vs LG PO4							
82-83	HS	HS	S	NS	NS	ID	ID
LG CFS vs LG NO3							
82-83	NS	NS	NS	NS	NS	ID	ID
LG TSS vs LG NO3							
82-83	HS	S	NS	NS	NS	ID	ID
CFS vs HCO3							
82-83	NS	S	HS	NS	NS	ID	ID
CFS vs TDS							
82-83	NS	S	HS	NS	HS	ID	ID

HS - Highly significant; 99% C.I. ANOVA $P < 0.01$
S - Significant; 95% C.I. ANOVA $P < 0.05$
NS - Not Significant at 95% C.I. ANOVA $P > 0.05$
ID - Insufficient Data - No Test

SWAN RIVER STATE FOREST

SUMMARY OF TESTS FOR SIGNIFICANCE

PARAMETER & SORT	GOAT CR.	SQUEEZER	SOUP B	S. FK. LOST	WOODWARD	S. WOODWARD	WHITETAIL	CILLY
LG CFS vs LG TSSM								
76-79	HS	HS	NS	HS	NS	NS	NS	HS
80-83	HS	HS	HS	HS	NS	ID	ID	ID
76-83	HS	HS	HS	HS	NS	ID	ID	ID
LG CSM vs LG TSSM								
76-79	HS	HS	NS	HS	NS	NS	NS	NS
80-83	HS	HS	HS	HS	NS	ID	ID	ID
76-83	HS	HS	HS	HS	NS	ID	ID	ID
LG CFS vs LG SPC								
76-79	HS	S	ID	HS	S	HS	ID	ID
80-83	HS	NS	HS	NS	NS	ID	ID	ID
76-83	HS	S	HS	NS	HS	ID	ID	ID
LG STG vs LG FLDQ	HS	HS	HS	HS	HS	ID	ID	ID

HS - Highly significant; 99% C.I.; ANOVA P< .01
S - Significant; 95% C.I.; ANOVA P < 0.05
NS - Not significant at 95% C.I.; ANOVA P > 0.05
ID - Insufficient data - No test

APPENDIX D

STREAMFLOW DATA - SWIFT CREEK @ CRAIN'S RANCH

WATER YEAR 1983

SWIFT CREEK @ CRAIN'S RANCH

DISCHARGE IN CFS, WATER YEAR OCTOBER 1982 TO SEPTEMBER 1983
(From instantaneous measurements, rating curve, and averaged data)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1							+67	+273	+990	+223	*79	
2							+70	+258	+879	*227	+78	
3	@64				+28		+67	*273	+844	*227	+76	
4						@67	+64	+289	*738	*227	#127	
5							*65	+340	*637	*227	*112	
6		@47					+65	+423	@536	*227	+97	
7							+67	+473	+683	*227	*95	#66
8						@68	+67	+380	+604	+230	*94	
9							+65	#358	+533	*221	@93	
10							+62	+297	+429	@212	+85	
11							+61	*301	+429	*209	+89	
12						@88	+59	+305	+418	#205	*87	
13							+59	+297	+408	*198	+85	@59
14							+56	+297	*405	*190	*82	
15							+56	+340	*402	+185	+79	
16							*63	+359	+398	+450	+76	
17		#29					+70	+378	+398	+331	#93	
18		+35					#114	+439	+378	*277	+73	
19		+43					@113	+484	+359	+223	*72	
20		+37					+128	+450	+340	+133	+70	
21		+35					+179	+668	#328	*170	*70	
22		+33					*230	@569	*308	*207	*70	
23				+31			+281	*715	+289	+243	*70	
24							+368	+861	*279	+251	+70	
25							+598	#789	*269	*221	+70	
26							+532	+1030	+258	*191	@74	
27							+439	+1091	+216	*161	*70	
28							*364	+1091	*227	+133	*70	
29						+47	+289	+1133	@237	+103	*70	
30						#57	*283	+1133	*230	*100	*70	
31						+70		+1050		+95	*70	
TOTAL	x1147	x1056	x961	x751	x713	x1109	5001	17144	13449	6525	2516	x1410
MEAN							167	553	448	211	81	
MAX							598	1133	990	450	127	
MIN							56	258	216	96	70	
CSM	.47	.45	.40	.31	.30	.46	2.14	7.09	5.74	2.71	1.04	.60
AC-FT	2271	2091	1903	1487	1412	2196	9902	33945	26629	12920	4982	2792
IN.	.55	.50	.46	.36	.34	.53	2.38	8.15	6.40	3.11	1.20	.67

WATER YEAR 1983 : TOTAL 51782
MEAN 142
MAX 1133
MIN 28
AC FT 102728

* Discharge averaged to derive this value
# Measurement by Department of State Lands
@ Measurement by U of M Biological Station
\+ Discharge estimated from station rating curve
x Monthly volume estimated from limited measurements and past data

APPENDIX E

MONTHLY AND ANNUAL RUNOFF FIGURES FOR SWIFT CREEK

AT CRAIN'S RANCH, 1973-1980 and 1983.

APPENDIX E

SWIFT CREEK AT CRAIN'S RANCH

MONTHLY AND ANNUAL RUNOFF

(ACRE FEET)

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	YEAR
1973	2300	1810	1130	1080	811	1370	4250	22750	18540	5750	2590	1870	64250
1974	1700	3400	3770	5240	3450	3100	15050	34970	70600	23030	6910	3550	174770
1975	4550	4100	4060	3410	2790	3730	5080	26810	45440	21600	9260	6840	137670
1976	3190	3770	2790	1660	1600	1690	10590	44460	23830	11560	6190	3470	115020
1977	2430	1730	993	791	1030	1020	8040	19830	9070	3560	1870	1840	52204
1978	1840	1530	1640	1090	857	2920	10890	33890	35550	13070	5440	3540	112257
1979	2300	1650	1350	768	1400	2240	5610	34670	20720	6350	3130	1700	81888
1980	1570	1200	1490	601	726	1060	11870	29080	16490	5920	3590	2660	76257
1983	2271	2091	1903	1487	1412	2196	9902	33945	26629	12920	4982	2792	102530
AVG 1973-1983	2461	2364	2125	1792	1564	2147	9031	31156	29652	11529	4909	3140	101870
% OF YEARLY FLOW	2.4	2.3	2.1	1.8	1.5	2.1	8.9	30.6	29.1	11.3	4.8	3.1	100%

1973 - 1980 Data from USGS, Station number 12365800.
1983 Data collected and compiled by Department of State Lands.

APPENDIX F

DESCRIPTION OF WATER QUALITY PARAMETERS

DESCRIPTION OF WATER QUALITY PARAMETERS

The following water quality variables have been recorded as data covered in this report, and are described in this section:

1. Alkalinity
2. Bicarbonate
3. Calcium
4. Chloride
5. Dissolved oxygen
6. Dissolved solids
7. Hardness
8. Magnesium
9. Nitrate
10. pH
11. Phosphorus
12. Potassium
13. Sodium
14. Specific conductance
15. Sulfate
16. Suspended solids
17. Temperature

Material discussed is based upon the following sources:

a) "Study and Interpretation of the Chemical Characteristics of Natural Water", by J. Hem, Geological Survey Water Supply Paper 1473, 2nd edition, 1970.

b) "Quality Criteria for Water", by U.S.E.P.A., July 1976.

c) "Standard Methods for the Examination of Water and Wastewater", 13th edition, 1971, by APHA, AWWA, WPCF.

Commonly used units used in this water quality report include the following:

1) Mg/l means milligram per liter, which is one part by weight of a substance in one million parts of water by volume, a liter. It is numerically interchangeable with parts per million (ppm) up to values of 7,000 mg/l. To put it into perspective, one mg/l is relatively comparable to one inch in 15.78 miles, or one minute in 1.90 years.

2) Micromhos is a unit of measure representing one-millionth of an electrical ohm, the resistance of water to carry an electrical current between two electrodes under specified conditions. Conductance is the reciprocal of resistance (ohms) and is reported in reciprocal ohms, called mhos. Since natural waters have conductance much less than 1 mhos and to avoid inconvenient decimals, data are reported in micromhos.

3) Concentration refers to a unit such as mg/l, the amount of a constituent in a given volume.

4) Loading or Yield refers to a daily or annual quantity and is a function of the concentration and flow rate.

5) Flow volumes are discussed in terms of cubic feet per second (cfs) and cfs per square mile (csm).

Alkalinity: Alkalinity is the total of chemical compounds in water that tend to elevate the water's pH above 4.5, such as bicarbonate, carbonate, phosphate and hydroxide ions. It is a measure of the buffering capacity of the water in resisting changes in the pH resulting from natural biological processes like photosynthesis or from man's activities like mining. It is desirable to have or maintain concentrations of at least 20 milligrams of alkalinity per liter of water for freshwater aquatic organisms, while higher levels of up to 350 mg/l will support a more diversified, productive trout fishery.

Bicarbonate: Bicarbonate is an anion, that along with other anions, contribute to the alkalinity of the water. Most surface streams contain less than 200 mg/l bicarbonate.

Calcium is usually the most abundant cation (positively charged particle) in most fresh water because of its wide distribution in the common minerals of rocks and soil. Calcium concentrations are usually highest in areas of sedimentary rock since limestone consists mostly of calcium carbonate. Calcium is also present in gypsum, anhydrite, flourite, the cementing agent in sandstone and in many igneous-rock materials. Calcium is a primary component of hardness. There are no undesirable levels of calcium concentration in water quality literature.

Chloride is present in low concentrations in most natural waters. Marine shales produce higher chloride concentrations, as does rainfall along ocean coasts. Chloride concentations should be below 100 mg/l for irrigation water, 170 mg/l for fisheries and 250 mg/l for domestic water supplies.

Dissolved oxygen is a function of water temperature, altitude, dissolved salts, and biological activity. For cold-water organisms, minimum dissolved oxygen concentration is 5.0 mg/l for growth and successful development of eggs buried in gravels, while 7 mg/l is much better and levels at or near saturation are best.

Dissolved oxygen also prevents leaching of iron and manganese from sediments, increases the efficiency of chlorination, and indicates a low residual of organic materials biolgically available for decomposition in municipal water supplies. On the negative side, high dissolved oxygen levels causes corrosion of metal surfaces in treatment plants, in pipes, and can increase the concentration of iron or other metals.

Dissolved solids, total dissolved solids or salts, and filtrable residue are equivalent terms referring to inorganic salts, small amounts of organic matter, and dissolved materials. The primary contributors to dissolved solids are the carbonates, sulfates, calcium, magnesium, and sodium in our streams.

Excess dissolved solids in drinking water are undesirable because of possible physiological effects, unpalatable taste, and higher treatment costs. Dissolved solids greater than 500 mg/l are objectionable in domestic water supplies. Dissolved solids of 500 mg/l or less are suitable for irrigation of crops. Generally, the larger the dissolved solids, the more productive the biological potential of our streams and lakes.

Hardness is caused by calcium, magnesium, and sometimes other metallic ions and is reported as the equivalent concentration of calcium carbonate ($CaCO_3$). Natural sources of hardness are limestones being dissolved by percolating rainwater made acidic by carbon dioxide dissolved in the rock and soil. A commonly used classification for the relative degree of hardness is given below:

Concentration, mg/l as $CaCO_3$	Rating
0 - 75	Soft
75 - 150	Moderately Hard
150 - 300	Hard
300 up	Very Hard

The effects of hardness on aquatic life is related to the ions comprising the hardness. Hardness derived from calcium may mitigate toxic effects of metal ions on fish.

Magnesium is found in dark-colored ferromagnesium minerals in igneous rock, in altered rocks and chlorite, montmorillomite and serpentine, and in sedimentary rocks in moderate amounts. It precipitates less rapidly than calcium, and is almost always present in lower concentrations than calcium. It is an essential element for man, is relatively non-toxic, and begins to make water taste bad at 100 mg/l. Fish can tolerate at least 400 mg/l before effects develop.

Nitrate is the final biological oxidation product of the nitrogen cycle and is usually present in concentrations below 1 mg/l in surface waters or 10 mg/l in groundwater. Diffuse sources of nitrogen are fertilizer and animal wastes, sanitary landfills, atmospheric fallout, fires, auto exhausts, mineralization of soil organic matter, and nitrogen-fixing bacteria on the roots of riparian vegetation like alder.

Nitrates become toxic to mammals and man when they are changed into nitrites in the gastrointestinal tract which then reaches the bloodstream, reacts directly with hemoglobin, and impairs oxygen transport. Infant deaths have occurred from ingesting well water containing over 10 mg/l nitrate nitrogen as N. Concentrations of nitrate or nitrite toxic to cold-water fisheries are rare in natural waters.

pH is a measure of the hydrogen ion activity in water. It is controlled naturally by the carbonate system consisting of carbon dioxide, carbonic acid, bicarbonate ion, and carbonate ions. pH is a very important factor in the chemical and biological systems of water because of its role in affecting the degree of dissociation of weak acids or bases, and therefore toxicity of many compounds.

A pH value of 7.0 is neutral, below 7.0 acid, and above 7.0 basic. A change of 1.0 pH unit represents a 10-fold change in hydrogen ion activity, not a one-fold change. pH in a stream varies seasonally and also during a day because of biological activity. pH naturally decreases somewhat with increasing altitude.

Criteria for desirable ranges in pH described in Montana's water quality standards for A-1 and B-1 waters are "Induced variation of pH within the range of 6.5 to 8.5 must be less than 0.5 unit. Natual pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0" EPA's report recommends a range of 5.0 to 9.0 for domestic water supplies and 6.5 to 9.0 for freshwater aquatic life.

Phosphorous occurs as the elemental form that is very toxic and bioaccumulatable like mercury, and as phosphate, a major nutrient requried for plant nutrition and growth. Total phosphorus as phosphate was analyzed for this report.

Phosphates come from some rock types, man's wastes and detergents, feedlots, concentrations of duck populations, tree leaves, and atmospheric fallout.

Phosphates easily leach through soils and also stick to sediment particles easily. To prevent biological nuisances and control acceleration of the eutrophication process, phosphates as P should not exceed 0.050 mg/l in any stream where it enters any lake or reservoir, or 0.025 mg/l within the lake or reservoir. In other streams, total phosphates as P should not exceed 0.10 mg/l to prevent algae nuisances or interference in the coagulation process in water treatment plants.

Potassium is found in feldspars, mica, clays and some evaporite sedimentary rocks. It is an essential plant nutrient where it tends to bio-accumulate. In streams, potassium is usually a few mg/l or less and does not vary much seasonally. Potassium is low in solubility in feldspars and it is also preferentially incorporated into clay or mica minerals which apparently account for its relative scarcity in water. It is not a problem in water use so no criteria are given.

Sodium compounds form almost 3 percent of the earth's crust and are extremely soluble in water. Sodium is retained by adsorption on mineral surfaces, especially clays, during cation exchange reactions. The relationship of sodium to calcium and potassium reflects their relative abundance in igneous rock and the rates at which they are attacked by leaching water.

Sodium is a large contributor to dissolved solids, and can influence crop production and cardiac disease in man. Persons on very restricted sodium diets should drink water containing less than 20 mg/l sodium, while water consumed in moderately restricted diets should contain no more than 270 mg/l sodium. For irrigation water, exchangeable sodium percentage of 10 to 15 percent is excessive if much swelling clay is present in the soil. Sodium absorption ratios of eight to 18 are acceptable for irrigation of non-sensitive crops or forage.

Specific conductance, also termed electrical conductivity, is the ability of water to conduct an electrical current at a specific temperature and dimension. The presence of major ions in solution makes the water conductive. There is often a good correlation between the major ions, dissolved solids, and the specific conductance value. Biological productivity of water also increases with specific conductance within the range found in the study area. Water used for irrigation should have 750 micromhos or less to avoid problems.

Sulfates occur naturally as a result of leaching from gypsum and pyrites, as a product of sulfur reducing bacteria, in rainfall, and from other sources. Groundwater low in sulfates will also be low in dissolved sulfides. Recommended limits are 250 mg/l for domestic water, 200 mg/l for irrigation, and 500 mg/l for stockwatering. Aquatic biota seem to thrive best when sulfate is under 50 mg/l.

Suspended solids (TSS) includes all particulate (non-dissolved) matter in water. This term is equivalent to: sediment, settleable solids, and nonfiltrable residue. As used in this report, TSS refers only to the suspended phase of sediment. Turbidity is not equivalent to TSS concentration, although it is sometimes correlated with it on a particular stream.

Suspended solids are derived from erosion of channels and the landscape, breakdown of organic material by acquatic organisms, dust, and other natural man-made sources. Sediment interferes with domestic water disinfection, recreational and aesthetic enjoyment of water, adversely affects fish and fish food populations (in many different ways), and impairs water's utility for irrigation. In larger river systems, navigation and reservoir sedimentation are

affected. One benefit of sediment is the removal of organic materials like pesticides whose chemical compounds attach to the sediment particle surface and later fall out of the water column into bottom sediments where they become less influential in water quality.

Montana water quality standards require "No increases are allowed above naturally occurring concentrations of sediment...which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, fish, birds or other wildlife." In this report, concentrations of suspended solids greater than 100 mg/l were flagged.

Sediment yield (discharge or production) is also discussed in this report for streams where daily and annual estimates were made. Yield data are given in tons per day, and tons per square mile per year to show relative differences amoung streams.

Temperature is the heat content of water and a critical factor in biological productivity, man's utility of the water, and to all life in water. Reproduction and growth are usually the most thermally limited of all life phases for aquatic life-forms. Water temperatures for cold-water fish should be below 69° F with 55 °F to 65 °F preferable for good growth reproduction.

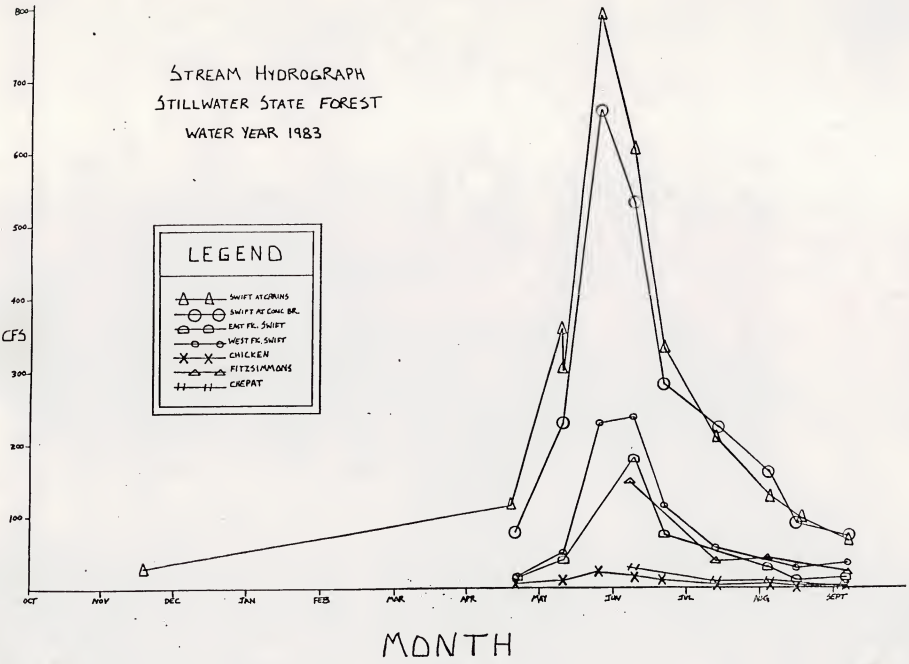
Montana water quality standards for A-1 and B-1 waters state: "A 1° F maximum increase above naturally occurring water temperture is allowed within the range of 32 °F to 66 °F; within the naturally occurring range of 66 °F to 66.5° F no discharge is allowed which will cause the water temperature to exceed 67° F; and where naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase is 0.5 °F. A 2 °F per hour maximum decreases below naturally occurring water temperatures is allowed when it is above 55° F, and a 2° F maximum decrease below natural...temperatures is allowed with the range of 55° F to 32° F.

APPENDIX C

STREAM HYDROGRAPHS

STILLWATER STATE FOREST

WATER YEAR 1983


STREAM HYDROGRAPH
STILLWATER STATE FOREST
WATER YEAR 1983
LEGEND
SWIFT AT GAINS
SWIFT AT COAL BR.
EAST FK. SWIFT
WEST FK. SWIFT
CHICKEN
FITZSIMMONS
CREPAT
CFS
800
700
600
500
400
300
200
100
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
MONTH